KEITHLEY

FSC

Model 227
Instruction Manual
Current Source (and Model 2271 Programming Option)

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WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment. During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from unauthorized modification or misuse of any product or part. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. Keithley Instruments, Inc. shall not be liable for any indirect, special or consequential damages.

STATEMENT OF CALIBRATION

This instrument has been inspected and tested in accordance with specifications published by Keithley Instruments, Inc.

The accuracy and calibration of this instrument are traceable to the National Bureau of Standards through equipment which is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of Keithley Instruments, Inc.

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Model 227
Current Source
(and Model 2271 Programming Option)

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WARNING

EXTREME CARE SHOULD BE TAKEN TO AVOID CONTACT WITH HIGH VOLTAGES WHEN MAKING CONNECTIONS TO EXTERNAL TERMINALS OR WHEN SERVICING THE MODEL 227 WITH TOP AND BOTTOM COVERS REMOVED.

Recommended Procedures for User Safety:

1. Detach line power cord when repairs or servicing must be performed with top and/or bottom covers removed.

2. Make certain third-wire ground pin on line power cord is connected to earth ground. This will ensure that the Model 227 chassis is at ground potential.

3. Before making connections anywhere on the front or rear panels, remove power to Model 227 by detaching the line power cord, or by setting the power switch to OFF, or by setting the OUTPUT SELECTOR switch to "SHORT" or "OPEN". Also, remove all external power Sources which may be connected between LO and CASE.

4. If the Model 227 LO terminal is to be floated above CASE, make certain that the metal link is removed between front panel LO and CASE terminals.

5. Make certain cable connections are well insulated and that no bare wires are exposed. Use connectors with fully enclosed and insulated wiring.

6. During calibration with top and/or bottom covers removed, extreme care must be taken to avoid contact with exposed circuitry. Use insulated tools and gloves for maximum safety. Various test points and adjustment circuitry may be up to 300 volts potential.

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SPECIFICATIONS

Calibrated at 25°C ± 3°C

AS A DC CONSTANT CURRENT SOURCE
OUTPUT:
Current: ±1 microampere (1000 microamperes full range) to ±1000 milliamperes in four decade ranges; 3-digit in-line readout; 11% overrange to 1110.
Voltage Compliance: ±300 volts on 100 milliampere range and lower. ±50 volts on 1000 milliampere range. Compliance limit continuously adjustable from approximately 3 volts to full voltage compliance.
Floating: ±500 volts maximum off chassis ground.
RESOLUTION: 0.005% of range, 3-digit readout.
ACCURACY: ±(0.5% of setting + 0.12% of range).

AS A BIPOLAR PROGRAMMABLE CONSTANT-CURRENT AMPLIFIER
VOLTAGE PROGRAMMING (INPUT): DC-coupled 0 to ±11 volts. Input resistance 10 kilohm. Input must be isolated from output load by greater than 10^6 ohms.
TRANSFER FUNCTION ±10 volts dc for ± full-range current output. Accuracy ±0.5%, zero offset less than 0.1% of range.
BANDWIDTH (-3dB): 600 Hz minimum.
OPTIONAL PROGRAMMING: Model 2271 option permits remote programming of Range, Magnitude, Polarity, Compliance Limit (See Model 2271).

GENERAL
STABILITY: ±(0.005% of setting + 0.005% of range)/°C. Short-term stability up to 30 days is masked by this temperature coefficient.
LOAD REGULATION: ±0.005% of range from no load to full load.
LINE REGULATION: ±0.005% of range for 10% change in line voltage.
NOISE: Wideband noise less than (0.03% of range + 2 millivolts) rms above 5 Hz.

ENVIRONMENT:
Operating: 0°C to 50°C. 0% to 80% relative humidity up to 35°C. Requires approximately 2-inch top and 6-inch rear panel clearances for air movement.
Storage: -25°C to 70°C.
CONNECTORS: Output (front and rear), Voltage Programming Input (rear); Binding Posts.
POWER: 90-110, 105-125, 195-235, 210-250 volts (switch selected), 50-60 Hz; 145 watts.
DIMENSIONS, WEIGHT: Style N, 5-1/4 in. half-rack, overall bench size 5-3/4 in. high x 8-3/4 in. wide x 15-1/4 in. deep (145 x 220 x 385 mm). Net weight, 24 pounds (10,9 kg).

Specifications for Model 2271 Programming Option.

Calibrated at 25°C ± 3°C

RANGE SELECT: Closure* on one of four lines selects range.

CURRENT SET:
Voltage Programming: Standard feature of Model 227. See specifications of 227.

Resistance Programming: Transfer function: 10% of full range per kilohm (±0.5%). Zero at approximately 11 kilohms. Stability: adds ±(0.01% of setting + 0.01% of range)/°C to Model 227 specification. Resistance must be isolated and shielded.

COMPLIANCE LIMIT:
External Operate: Closure* enables external control of both span and limit. Open enables 227 front-panel control.
Span Select: Closure* enables compliance limit to be set from 10 to 300 volts, open makes span 4 to 50 volts.
Compliance Limit Set: Resistance programmed, nonlinear transfer function, 0Ω yields high end of span, 25kΩ yields approximately mid span, open circuit yields low end. Resistance must be isolated and shielded.
Flag (Output): Logic "0" (≡<0.4V drop while sinking 16mA to external power supply Lo) appears when 227 is in compliance limit. Logic "1" (≡>2.4V at up to 400μA referenced to supply Lo) appears when 227 is not in compliance limit.
REQUIRED CONTROL LEVELS:
*CLOSURE ≡ Closure to external power supply LO within 0.5 volt while sinking 50mA (range-select for 1-ampere range requires sinking 100mA).
OPEN ≡ >2 kilohms referenced to external power supply Lo.
EXTERNAL POWER SUPPLY: Requires external power supply of 5 to 6 volts @ 200mA.
CONNECTOR: DAM-15S type mounts on 227 rear panel.

ACCESSORIES SUPPLIED: Mating connector.

SECTION 1. GENERAL INFORMATION

1-1. INTRODUCTION. The Model 227 is a dc current source with full range current from 1 milliampere to 1000 milliamperes. The Model 227 provides a compliance up to 300 volts on 1mA, 10mA, and 100mA ranges or up to 50 volts on 1000mA range. The output is bipolar. Load regulation is ±0.005% of range from no load to full load.

1-2. FEATURES.

a. Three digit readout has least significant digit continuously adjustable using Fine Current Control. Typical setability is 1 degree of rotation (which corresponds to 0.005% of full range).

b. Compliance limit is adjustable up to 300 volts.

c. Output can be floated to ±500 volts above case.

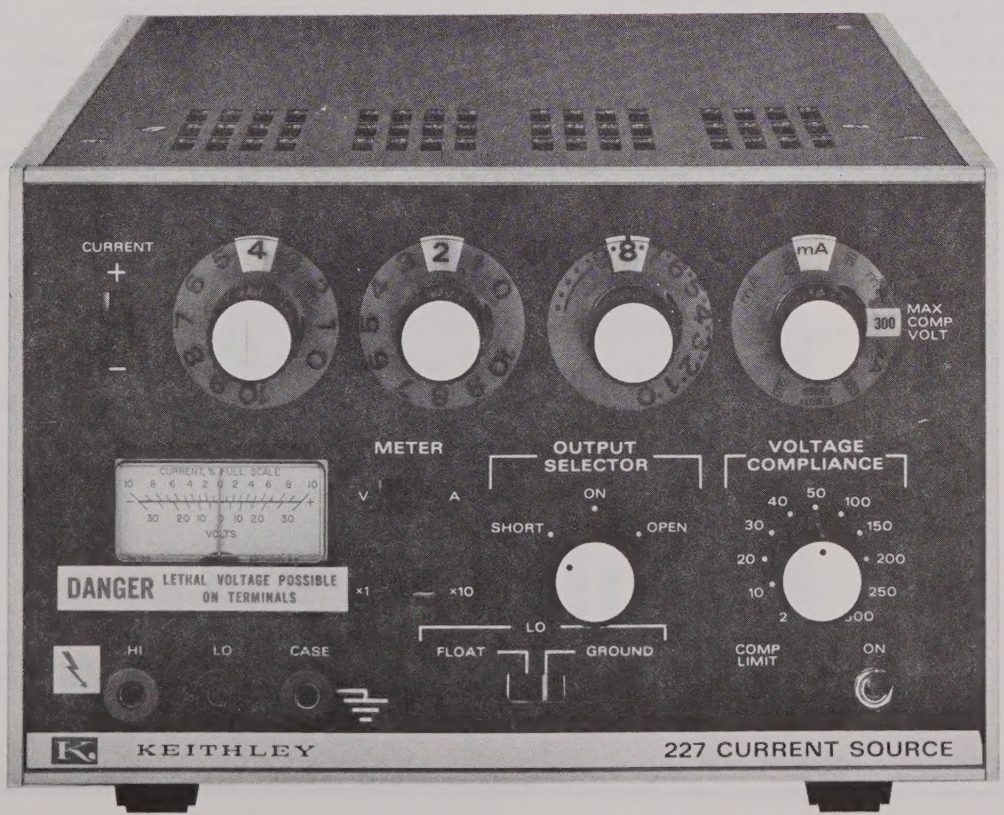
d. Voltage programming input is standard.

e. Model 2271 Programming option is available factory installed.

1-3. WARRANTY INFORMATION. The warranty is stated on the inside front cover of the manual. If there is a need for service, contact your Keithley representative or authorized repair facility as given in our catalog. The Service Form supplied at the back of the manual should be used to provide the repair facility with adequate information concerning any difficulty.

1-4. CHANGE NOTICE. Improvements or changes to the instrument not incorporated into the manual will be explained on a yellow change notice sheet attached to the inside back cover of the manual.

1-5. PROGRAMMING OPTION. The Model 2271 is a factory-installed option which enables remote programming of range, magnitude, polarity, and compliance. Current magnitude and compliance can be resistance programmed. Range and compliance maximum are selected by means of closure to external power supply common. An external +5 volt supply is required to energize relay coils in the Model 2271.



SECTION 2. INITIAL PREPARATION

2-1. GENERAL. This section provides information needed for incoming inspection and preparation for use.

2-2. INSPECTION. The Model 227 was carefully inspected both mechanically and electrically before shipment. Upon receiving the instrument, check for any obvious damage which may have occurred during transit. Report any damages to the shipping agent. To verify the electrical specifications, follow the procedures in Section 5.

2-3. PREPARATION FOR USE.

a. How to Set Line Switches. The Model 227 has two rear panel line switches which are used to select line voltage ranges of 90-110V, 105-125V, 195-235V, or 210-250V as shown in Figure 2. The line switches are identified as 117/234V (S303) and LOW/NORM (S302). Once the line voltage to be used has been determined, then the line voltage range should be selected from the four ranges available on the Model 227. For example, when the line voltage to be used is within the range from 105 to 125 volts, then the line switches should be set to "117V" and "NORM" positions. If the line voltage to be used is within either of two overlapping ranges, such as 107 volts, then either range may be selected (117V, LOW, or 117V NORM, for this particular example). Line voltages which are not covered by any one of the four ranges require an appropriate step-up or step-down transformer.

b. Line Fuse Requirements. The Model 227 uses a 2-1/2A 3AG slo-blo fuse for the range 90-125V and a 1-1/4A line fuse for the range 195-250V. The Line Fuse is located on rear panel as shown in Figure 2.

c. Line Power Connections. An accessory line cord is furnished with the Model 227. The 3-wire, 8 foot (244 cm) line cord mates with the rear panel receptacle P306. Extra line cords can be ordered from Keithley by specifying Keithley Part No. CO-7.

d. Mounting and Ventilation.

1. Bench Mounting. The Model 227 requires a 2 inch clearance above the top cover and at least a 6 inch clearance at the back panel to allow for air circulation. Care should be taken to keep the filter on the top cover clear of any obstruction. (See Filter Replacement, paragraph 2-3 d3.)

2. Rack Mounting. The Model 227 can be rack mounted using accessory Model 1008 Single Rack Mounting Kit (and Model 2272 Rack Panel Adapter, which allows clearance over the top cover of the Model 227). See Section 4 for installation instructions. The Model 227 requires 2 inch clearance above the top cover and at least 6 inch clearance at the back panel to allow for air circulation. Care should be taken to keep the filter on the top cover clear of an obstruction.

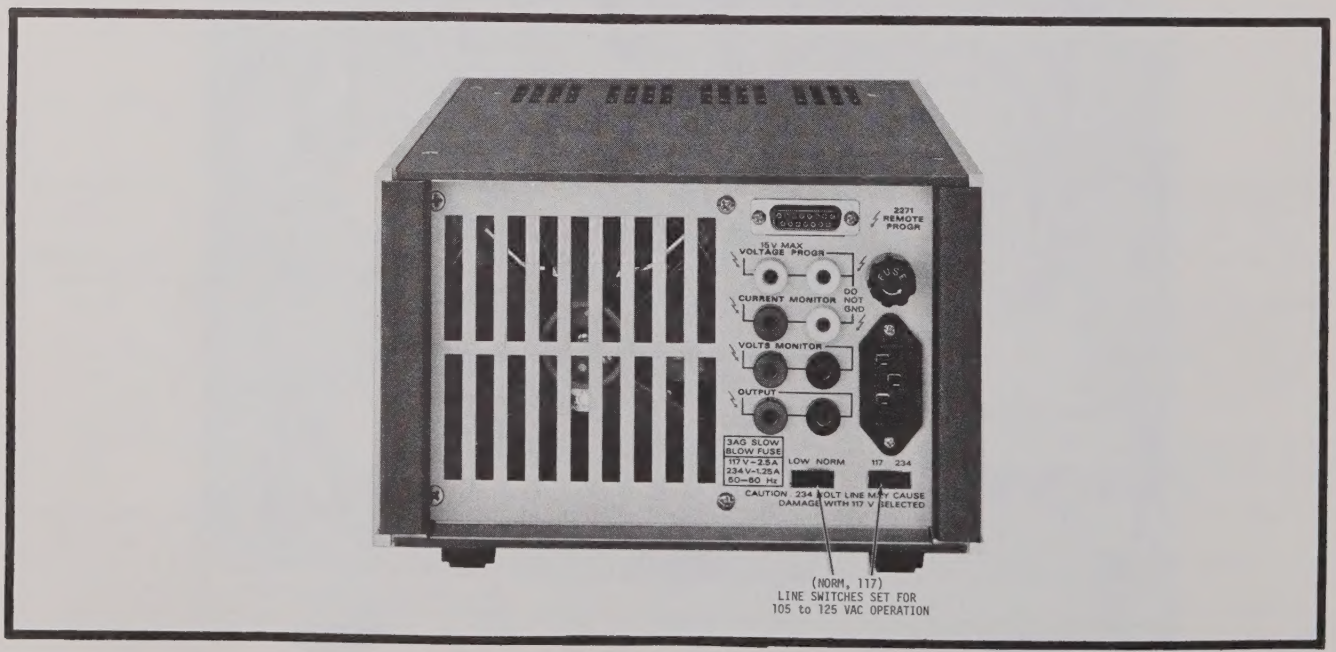


FIGURE 2. Rear Panel Showing Line Switches.

IMPORTANT

The Model 227 has been designed to operate at up to 50°C ambient temperature. Sufficient ventilation should be provided so that the fan which circulates air through the Model 227 is able to maintain a flow of cooling air as shown in Figure 3. Should a failure of the fan occur or abnormal internal heating occur, the Model 227 automatically shuts down. The thermal cut-out in the Model 227 will operate regardless of the condition of the fan.

3. Filter Replacement. The air filter in the Model 227 is located as shown in Figure 4. The filter should be cleaned or replaced at least once per month under laboratory conditions, or more often when used in industrial environments. The filter can be checked and replaced by removing the top cover. Replace with Keithley Part No. 25791.

RECOMMENDED CLEANING INSTRUCTIONS: To clean the filter, remove top cover, detach filter from cover, flush filter with water, and recoat with Research Products "Super Filter Coat Adhesive". (Research Products Corp., 1015 E. Washington Avenue, Madison, WI. 53701.)

CAUTION

Read and understand the following safety precautions before power is applied to the Model 227 or connections are made to any terminals.

e. Safety Precautions. The Model 227 should be operated with care since potentially lethal voltages are present at various terminals on the front and rear panels.

IMPORTANT

Whenever it is necessary to turn power on or off to the Model 227, set the OUTPUT SELECTOR to SHORT or OPEN and set the VOLTAGE COMPLIANCE control to minimum voltage. This will ensure that power turn on and turn off action will not affect the load.

1. How to Safely Disconnect the Load. The OUTPUT SELECTOR Switch (S104) should be used to safely disconnect the load from the Model 227 output.

a). SHORT Position. This position should be used when disconnecting a resistive or inductive load. In this position, the Model 227 output current by-passes the output terminals. In addition, a 10 ohm, 1/2 watt resistor is connected across the output terminal. As a result, the SHORT position should not be used with capacitive loads greater than 1μF or external voltage supplies since damage to the Model 227 and the load could result.

b). OPEN Position. This position should be used when disconnecting a capacitive load. In this position, the Model 227 output current by-passes the output terminals. The output terminals are open. Do not use this position with inductive loads since a high voltage may be instantaneously developed at the output terminals due to an interruption of current flowing through the inductance causing possible damage to the Model 227.

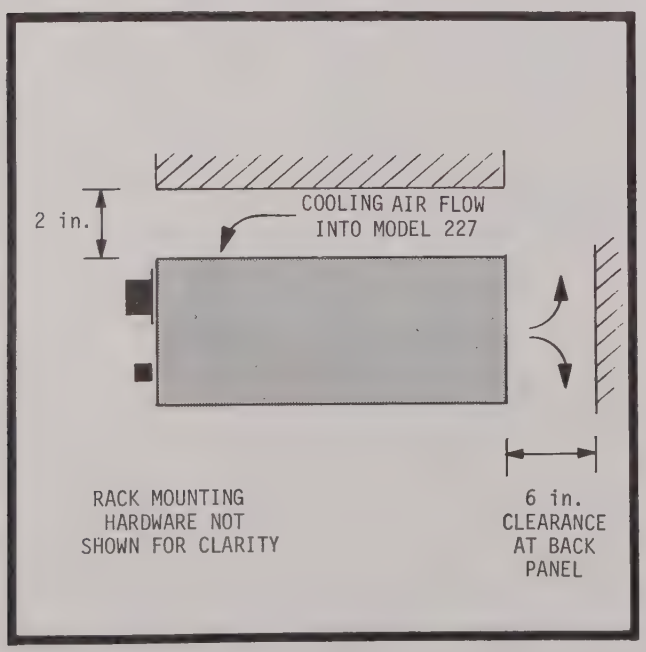


FIGURE 3. Recommended Mounting and Ventilation.

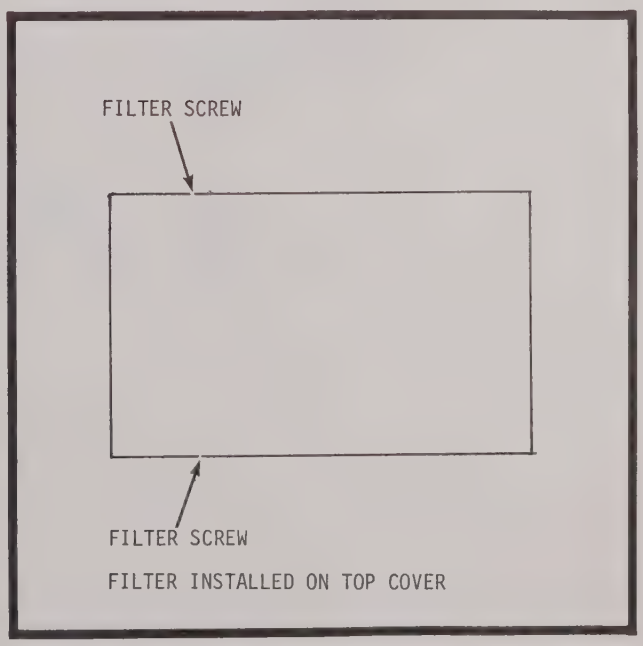


FIGURE 4. Location of Air Filter.

2. How to Safely Use Front and Rear Terminals. (See Figure 5 and Table 2-1 for a complete listing of all voltages present.)

a). Front and Rear Panel HI Terminal (J109, J107). These terminals provide current output up to the maximum compliance voltage as set on the Model 227 (either by front panel range switch or by Model 2271 Remote Programming). As a result, the terminals can be up to 305 volts above LO (Black) depending on range selected. If the LO terminal is floating at 500 volts above CASE (Green), then up to 805 volts can be present at HI. For operator safety, set COMPLIANCE LIMIT to minimum or set OUTPUT SELECTOR Switch to "SHORT" or "OPEN".

b). Front and Rear Panel LO Terminal. Terminals J110 (Black) and J108 (Black) can be at 500 volts if LO is floating above CASE (Green).

c). VOLTAGE PROGRAMMING Terminal. Terminals J101 (Blue) and J102 (Black) float at output HI potential and can be up to 306 volts above output LO (Black).

d). CURRENT MONITOR Terminals. Terminals J103 and J104 float at output HI potential and can be up to 305 volts above output LO.

e). VOLTS MONITOR Terminal. Terminal J105 is a buffered output and can be up to 305 volts above output LO. Terminal J106 at the same potential as output LO.

TABLE 2-1.
Voltages at Front and Rear Panel Terminals.

Name	Circuit Desig.	Maximum Voltage Referenced to CASE J111 Grounded LO	Floating LO
OUTPUT HI	J109 (Front)	305 V	805 V
OUTPUT HI	J107 (Rear)	305 V	805 V
OUTPUT LO	J110 (Front)	0 V	500 V
OUTPUT LO	J108 (Rear)	0 V	500 V
VOLTS MONITOR HI	J105	305 V	805 V
VOLTS MONITOR LO	J106	0 V	500 V
CURRENT MONITOR HI*	J103	305 V	805 V
CURRENT MONITOR LO*	J104	306 V	806 V
VOLT PROGRAM HI*	J101	306 V	806 V
VOLT PROGRAM LO*	J102	306 V	806 V
RESISTANCE PROGRAM HI*	J401, pin 2	306 V	806 V
RESISTANCE PROGRAM LO*	J401, pin 10	306 V	806 V

*IMPORTANT

These terminals are fused by F101 which is a type 8AG fast-acting fuse rated at 0.125 amperes. A short circuit to output LO will cause the fuse to blow within 5 seconds. Warning: Instantaneous current could exceed 200mA until fuse blows.

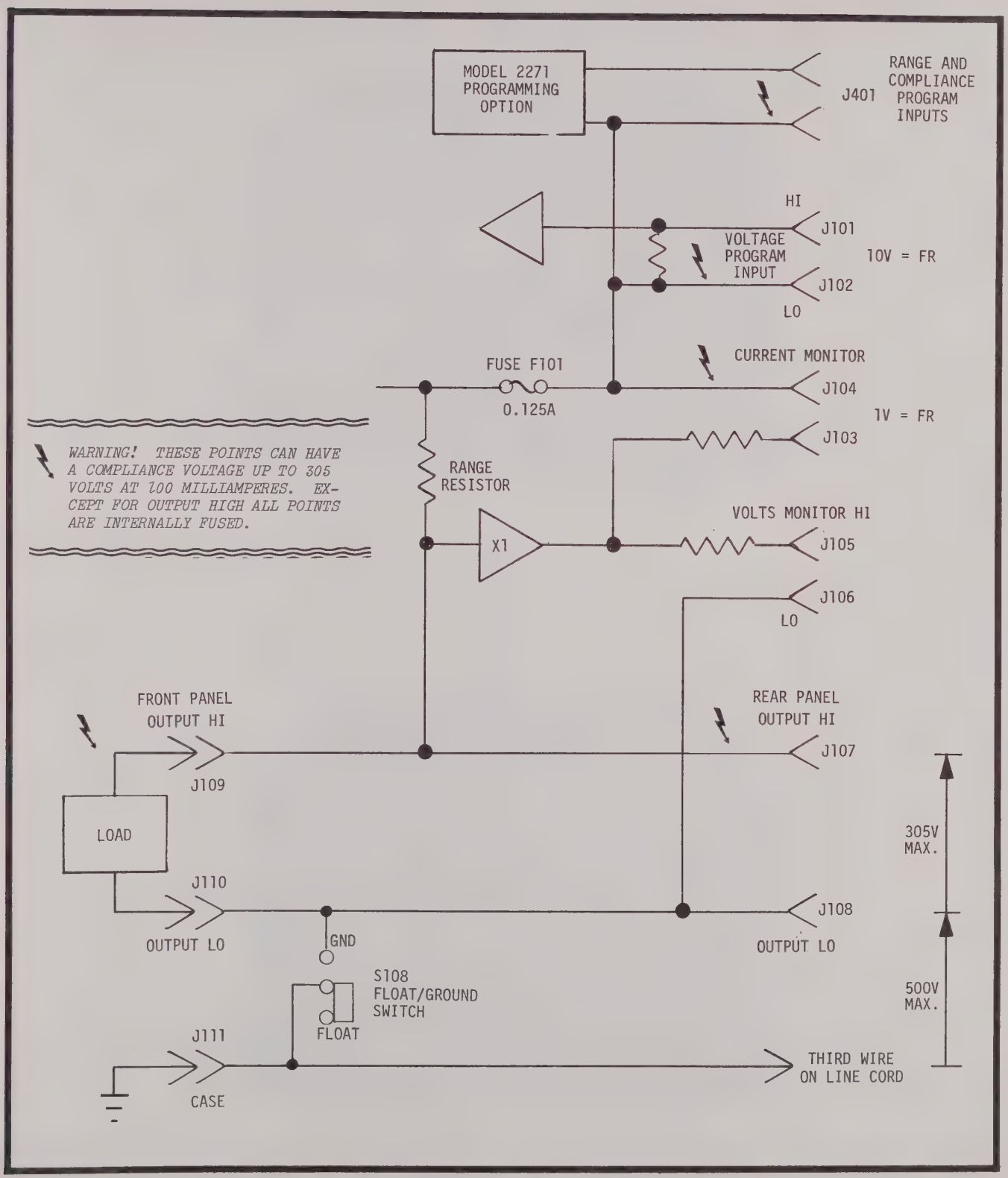


FIGURE 5. Voltage Levels Present at Front and Rear Panel Terminals.

TABLE 2-2.
Front and Rear Panel Controls and Connectors.

Control or Connector	Description	Paragraph
Front Panel		
Power Switch (S301)	Applies power to instrument.	3-3b
OUTPUT SELECTOR Switch (S104)	Sets output configuration. (Should be used to safely disconnect the output load.)	2-3e
Range Switch (S101)	Sets full range current in decade steps (1000μA, 10mA, 100mA, and 1000mA).	3-3f
Decade Selector Switches (S102, S103)	These switches are used with Fine Current Control to set current output. Each switch has discrete decade steps from 1 to 10, while the Fine Current Control is continuously adjustable.	3-3g
Fine Current Control (R124)	Adjusts current between 0.000 to 0.011 times full range. This control is continuously adjustable. Typical setability of 1 degree of rotation or 0.005% of full range.	3-3g
CURRENT Polarity Switch (S105)	Sets output polarity.	3-3e
VOLTAGE COMPLIANCE (R101)	Adjusts compliance voltage limit up to 300 volts.	3-3d
METER V/A Switch (S106)	Sets meter to read voltage or current.	
METER X1/X10 Switch (S107)	Sets meter sensitivity for scale factor of X1 or X10.	
COMP LIMIT Indicator (DS104)	Indicates compliance limit mode when lighted.	3-4a1
Output HI (J109)	Connection to output HI. (In parallel with J107.)	3-2a1
Output LO (J110)*	Connection to output LO. (In parallel with J108.)	3-2a1
CASE (J111)* FLOAT/GROUND Switch (S108)	Chassis ground. (Connected to third wire ground.) Connects LO and CASE when set to GROUND.	3-2a1
Rear Panel		
REMOTE PROGRAM (J401)	Provides inputs and outputs for range, current, and voltage control. (Available when Model 2271 option is installed.)	3-2b2
VOLTAGE PROGRAM (J101, J102)	Provides input for voltage programming.	3-2b1
CURRENT MONITOR (J103, J104)	Provides output for monitoring current (1V = Full Range).	3-2a3
VOLTS MONITOR (J105, J106)	Provides output for monitoring voltage (up to 300 volts)	3-2a2
Output HI, LO (J107, J108)	Outputs which are in parallel with front panel HI and LO.	3-2a1

NOTE*

On some models a shorting link is provided to connect LO and CASE. On models presently manufactured, banana type terminals are used instead of binding post type and the shorting link is no longer used. A front panel FLOAT/GROUND Switch has been added to permit a connection between LO and CASE for grounded applications.

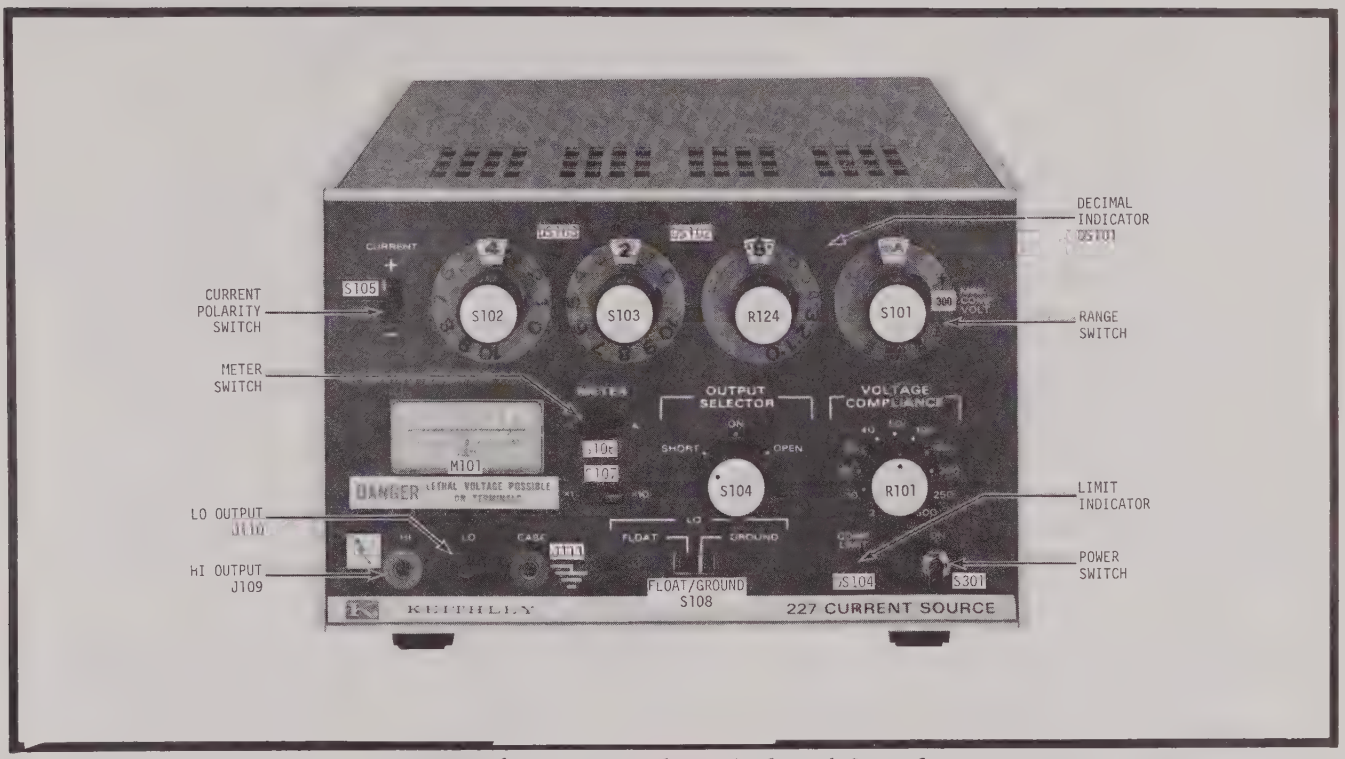


FIGURE 6. Front Panel Terminals and Controls.

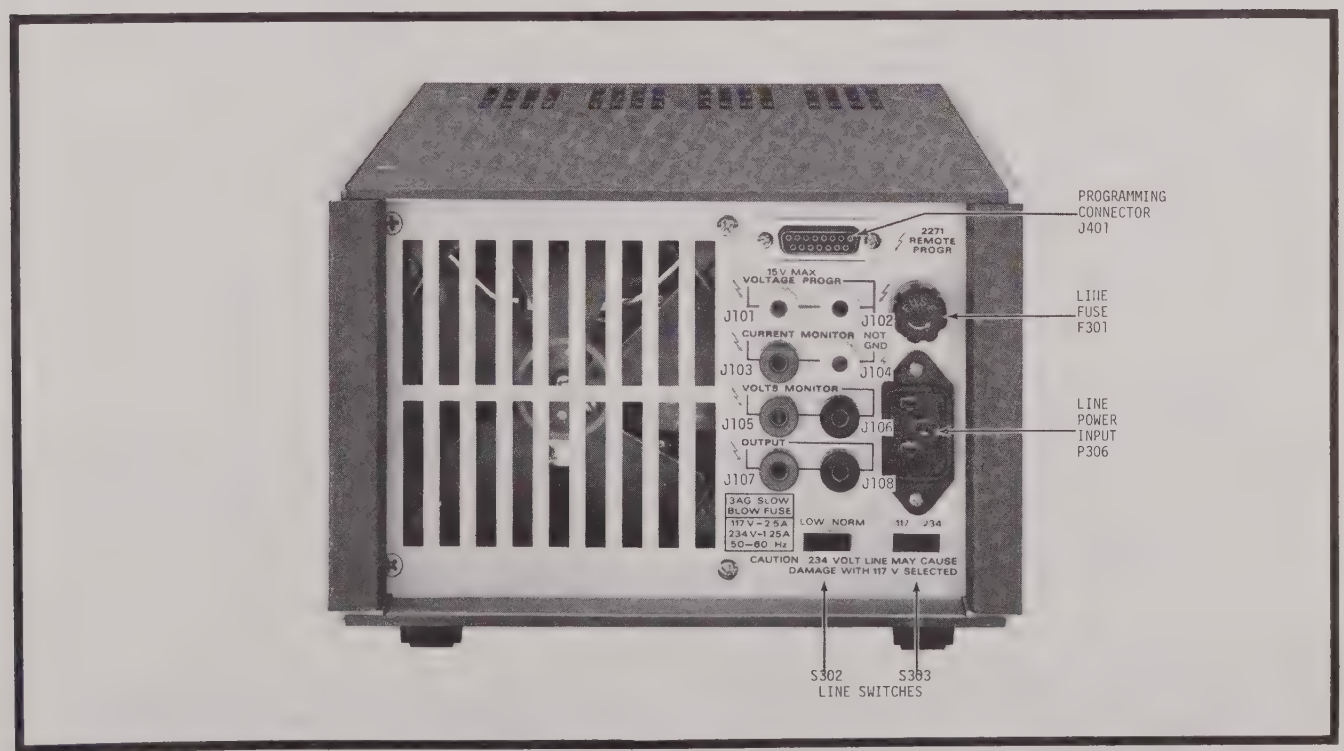


FIGURE 7. Rear Panel Terminals.

SECTION 3. OPERATING INSTRUCTIONS

3-1. GENERAL. This section provides information to operate the Model 227 as a current source or programmable current amplifier.

3-2. HOW TO MAKE CONNECTIONS

a. Output Connections.

1. Current Output. Output current is provided at the red (HI, J109) and black (LO, J110) banana posts on the front panel. The green (CASE, J111) banana post is internally connected to chassis and line cord ground. When connecting a load to the Model 227 use a cable rated at 1000 volts and 1 ampere. A second set of banana posts are provided on the rear panel (red, J107 and black, J108). Make certain no connections are made to rear panel terminals when the front panel output terminals are being used.

CAUTION

Set compliance control to minimum and OUTPUT SELECTOR to either SHORT or OPEN before connections are made.

2. VOLTAGE MONITOR Output. The rear panel VOLTS MONITOR banana post (J105) permits the user to monitor the output voltage of the Model 227 without disturbing the output current. This buffered output has an output resistance of 10 kilohms. As a result a voltmeter having greater than 100 megohms input resistance should be used to keep the loading error below 0.01%.

3. CURRENT MONITOR Output. The rear panel CURRENT MONITOR banana posts (blue, J103, and white, J104) permits the user to monitor the current of the Model 227. This output provides a 1 volt dc level corresponding to full range output current. Output resistance is 10 kilohms. Both blue and white terminals are floating at the output HI voltage. Monitor voltage polarity is opposite of output current polarity.

b. Input Connections.

1. VOLTAGE PROGRAM Input. The yellow (J101) and white (J102) banana posts permit the user to set the output current of the Model 227 on a given range using a voltage from 0 to ±10 volts. The input is dc coupled and has an input resistance of 10K ohms. The output current can also be modulated by using a signal generator with floating output. The transfer characteristics of the voltage program input is shown in Figure 19. See Section 3-7 for a detailed discussion of voltage programming.

2. PROGRAM Option. When the Model 2271 Remote Program option is installed, the Model 227 can be remotely programmed to select range, current level, and compliance voltage. A 15-pin connector (J401) is provided when the Model 2271 is installed at the factory. See Section 3-8 for a detailed discussion of the remote program option.

3-3. HOW TO SET OUTPUT CURRENT.

a. Set OUTPUT SELECTOR Switch (S104) to either "SHORT" or "OPEN" standby positions to eliminate the possibility of shock or damage to the load. (See also Section 2-3e for important safety precautions.)

b. Apply power to instrument using Power Switch S301.

c. Determine compliance voltage required.

d. Set VOLTAGE COMPLIANCE Control (R101) to the desired maximum voltage.

1. This control is continuously variable and sets the compliance voltage limit from approx. 3 volts to 50 volts maximum on 1000mA range and up to 300 volts on lower ranges.

2. This control has a tapered resistance such that greater resolution is provided for compliance voltage settings under 60 volts. Figure 9 shows the voltage output versus % rotation of the control.

e. Set current polarity using Polarity Switch (S105).

f. Set current range using Range Switch (S101).

1. This switch sets the maximum current in four decades (1000μA, 10mA, 100mA, and 1000mA).

2. The dial is designated in terms of engineering units, either μA (microamperes) or mA (milliamperes).

3. Full range is determined by the decimal point position (lighted) and the engineering unit displayed (μA or mA).

g. Set current output using Decade Switches (S102, S103) and Fine Current Control (R124).

1. The Decade Switches set the two most significant digits in decade steps from 0 to 10.

2. The Fine Control provides continuous adjustment of the least significant digit with typical setability of 1 degree of rotation (corresponding to 0.005% of full range). The dial has a maximum readout of 10 plus approximately 10% adjustment beyond 10.

h. Connect the load as described in Section 3-2a.

i. Set OUTPUT SELECTOR Switch to "ON".

1. When set to "ON" the Model 227 can develop up to 50 volts at 1000mA or 300 volts at 100mA.

2. Care should be taken when connecting the Model 227 to inductive or capacitive loads. See Sections 2-3e and 3-4b.

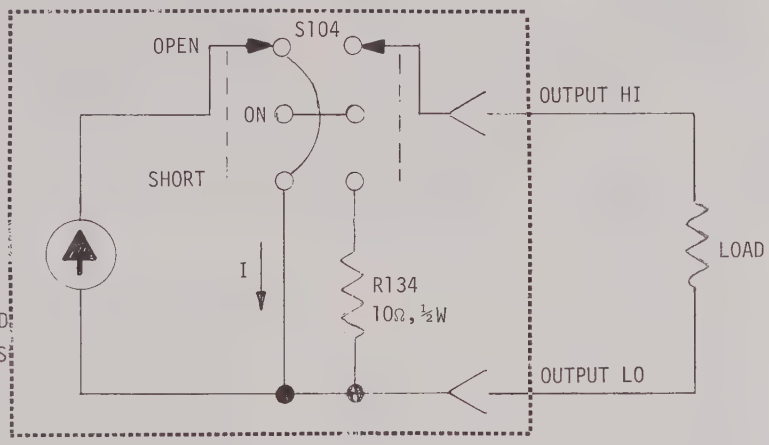


FIGURE 8a.
"OPEN" POSITION
NO VOLTAGE IS DEVELOPED
ACROSS OUTPUT TERMINALS

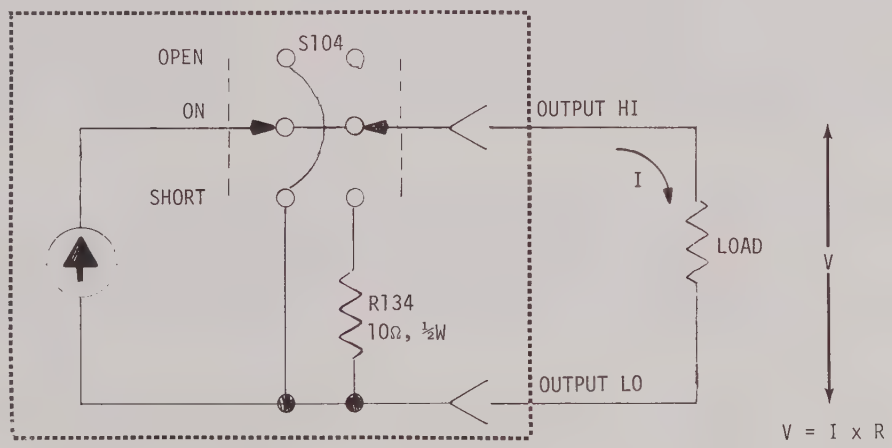


FIGURE 8b.
"ON" POSITION

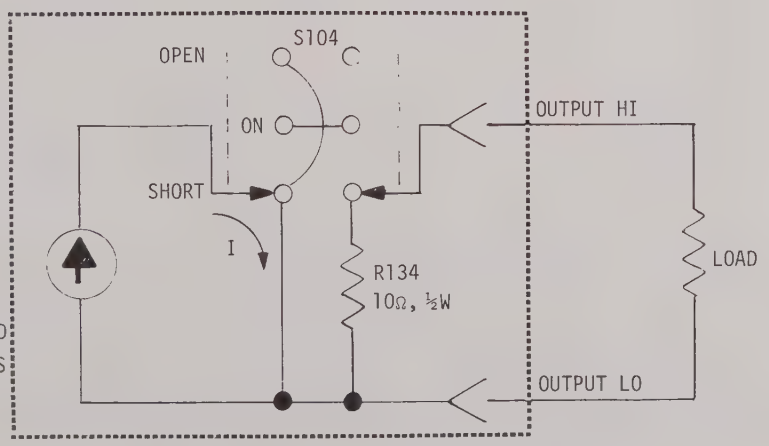


FIGURE 8c.
"SHORT" POSITION
NO VOLTAGE IS DEVELOPED
ACROSS OUTPUT TERMINALS

FIGURE 8a,b,c. Output Selector Switch Positions.

TABLE 3-1.
Summary of Current Settings.

Range Settings	Max. Dial Settings	Max. Voltage	Max. Power to Load
1000 mA	1110. mA	50V	55.5W
100 mA	111.0 mA	300V	33.3W
10 mA	11.10 mA	300V	3.33W
1000 µA	1110. µA	300V	0.333W

3-4. OPERATING CONSIDERATIONS.

a. How to Use with Resistive Loads.

1. Operation as a Current Source. The Model 227 can deliver a constant current up to the compliance voltage setting. Current is set by use of the Range and Decade Dials on the front panel. With a resistive load as shown in Figure 10, the voltage developed across the load resistance R_L is: $V = I \times R_L$. If the compliance voltage setting V_c is less than the voltage V , then the Model 227 will automatically limit the voltage to V_c and the LIMIT indicator will be lighted.

2. Operation as a Current Sink. The Model 227 can be used as a current sink as shown in Figure 11. In this case, the current flow is into the Model 227. The output voltage V_o is a function of E, I , and R_L where:

$V_o = E - I R_L$
E = external voltage source
I = current setting on Model 227
R_L = load resistance

CAUTION

When the Model 227 is connected so as to sink current (that is, power is delivered to the Model 227 by an external power supply), care should be taken to limit the power delivered to the terminals of the Model 227 as shown in Figures 14a and 14b. If power dissipated within the Model 227 exceeds these limitations overheating and damage to the Model 227 could occur. For example, if the external power supply is capable of delivering greater than 700 milliamperes, then the voltage across the Model 227 output terminals must be less than 50 volts (approximately 46 watts maximum internal dissipation allowed).

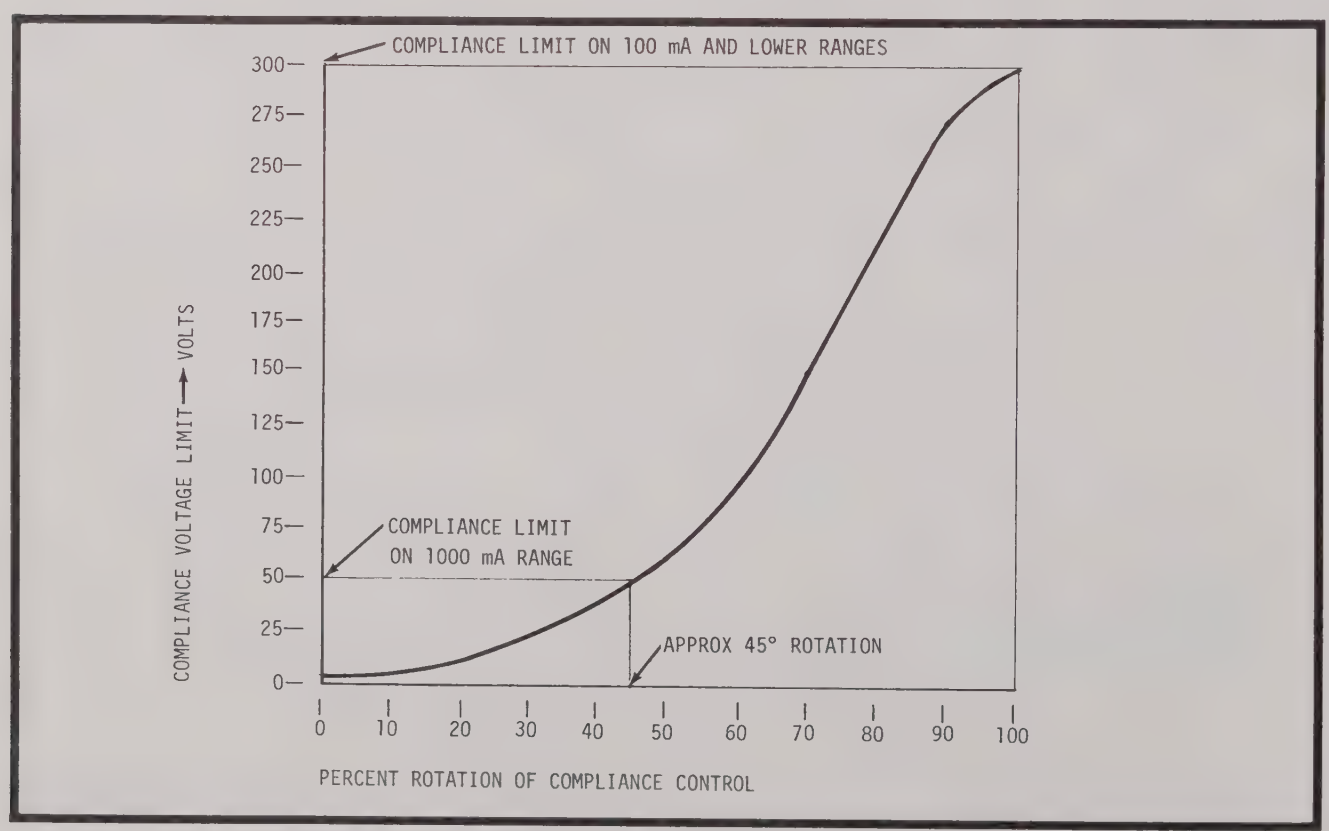
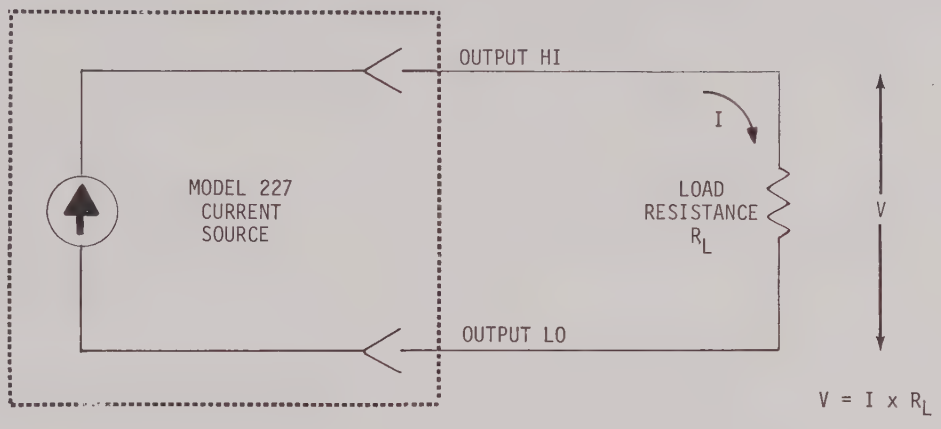
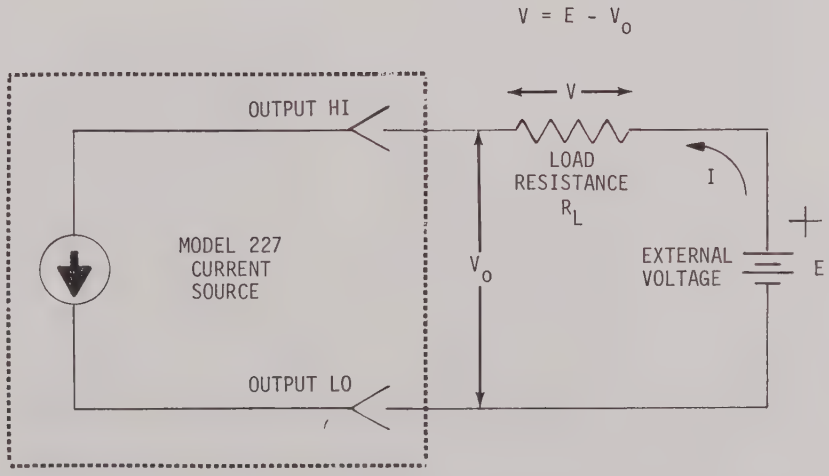


FIGURE 9. Voltage Output Versus % Rotation for Compliance Control.



FOR RESISTIVE LOAD MODEL 227 WILL DELIVER DIALED CURRENT UP TO COMPLIANCE VOLTAGE

FIGURE 10. Connections as a Current Source with Resistive Load.



FOR RESISTIVE LOAD MODEL 227 WILL DELIVER DIALED CURRENT UP TO COMPLIANCE VOLTAGE $V_o = V_c$
OUTPUT VOLTAGE V_o MUST REMAIN WITHIN THE AREA SHOWN IN FIGURE 15a OR 15b TO AVOID DAMAGE TO MODEL 227

FIGURE 11. Connections as a Current Sink with Resistive Load.

b. How to Use with Capacitive or Inductive Loads.

1. Capacitive Load. When a capacitive load is connected, the Model 227 delivers a constant current until the voltage developed reaches the compliance voltage setting V_c. The voltage V_o charges to a maximum V_c according to the following equation:

$$V_o = \frac{1}{C} \int I \, dt \text{ up to } V_c \text{ (maximum)}$$

where C = load capacitance

When using a capacitive load, it is preferred to use the "OPEN" standby position when not making measurements to avoid shock hazard due to compliance voltage at the output terminals. Do not use the "SHORT" position since the voltage on the capacitive load will be discharged.

2. Inductive Load. When an inductive load is connected, the Model 227 delivers a constant current the same as for a resistive load. However, to maintain stability the ratio load inductance L (Henries) to load resistance R (ohms) should be smaller than approximately 10^{-6}. This ratio is non-linear and depends on the amount of inductance and the range so that larger values of L/R may be needed to prevent oscillations. A typical calculation of the L-to-R ratio is as follows:

For R = 1000 ohms and L = 1 millihenry,

$$L/R = \frac{1 \times 10^{-3}h}{10^{3}\Omega} = 1 \times 10^{-6}.$$

If oscillations occur at the output, add series resistance to lower the L-to-R ratio. When using an inductive load, it is preferred to use the "SHORT" standby position when not making measurements to avoid shock hazard due to open terminals. Also, the current should be dialed to zero before disconnecting an inductive load.

c. How to Use the Compliance Control. The compliance control sets the maximum compliance from approximately 3 volts to 50 volts on the 1000mA range and from approximately 3 volts to 300 volts on 1mA, 10mA, and 100mA ranges. The compliance voltage should be preset with no load connected. The front panel meter can be used as a guide to setting compliance. (Set METER switches to V and X1 or X10 as appropriate.) The rear panel VOLTS MONITOR output can be used to adjust the compliance more accurately. Use a voltmeter with an input resistance of at least 100 megohms to avoid loading error at VOLTS MONITOR output. The control has a tapered characteristic such that the first 50% of rotation represents a variation from 3 to 60 volts to allow more resolution at lower compliances.

3-5. MEASUREMENT CONSIDERATIONS.

a. How to Determine Dial Accuracy. The accuracy is specified as ±(0.5% of output + 0.12% of range). Since the total accuracy of the Model 227 is the sum of the reading accuracy and the full range accuracy, the user should select the lowest full range for best possible accuracy. Table 3-2 shows the total accuracy for typical dial settings.

TABLE 3-2.
Comparison of Accuracy for Typical Current Settings.

Output Current	Decade Dial Settings	Range Setting	Total Accuracy
1mA	0-0-1	1000mA	±1.205 mA
1mA	0-1-0	100mA	±.125 mA
1mA	1-0-0	10mA	±.017 mA
1mA	10-0-0	1000µA	±.0062 mA

b. How to Determine Stability.

1. Time Stability. Stability with time is taken into account by the basic accuracy specification. (See also Temperature Stability in the following paragraph.)

2. Temperature Stability. Stability is specified as ±(50ppm/°C of range + 50ppm/°C of dial setting). The lowest full range for the best possible stability should be selected. Maximum allowable ambient temperature is 50°C.

c. How to Determine Line Regulation. Line regulation is ±(.005% of full range) for a corresponding 10% change in line voltage. For example, for a nominal line voltage 115V, the variation would be ±11.5V.

d. How to Determine Load Regulation. The load regulation is specified as ±(.005% of full range) for a change from no-load to full-load. The no-load to full-load variation corresponds to an output compliance voltage change of from 0 to 300V on the 1mA, 10mA, and 100mA ranges and from 0 to 50V on the 1000 mA range.

e. How to Determine Output Resistance.

1. DC Output Resistance. The effective output resistance of the Model 227 can be determined by calculations from the load regulation specification.

For the 100mA range:
$R_L = 3 \times 10^{3}\Omega$ and % regulation = .005%.

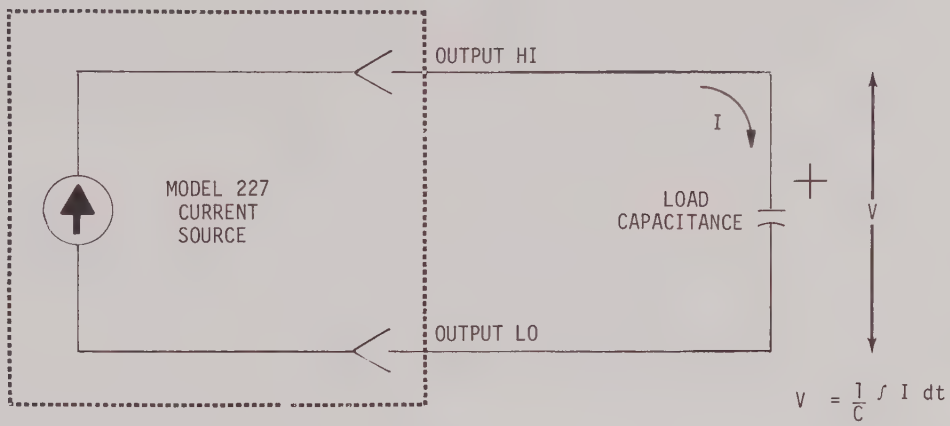
$$\text{Since \% regulation} = 100 \times \frac{R_L}{R_O + R_L}$$

$$\text{then } R_O = \frac{100\ R_L}{\text{\% Reg.}}$$

$$\text{or } R_O = \frac{100 \times 3 \times 10^{3}}{.005} = 6 \times 10^{7}\Omega$$

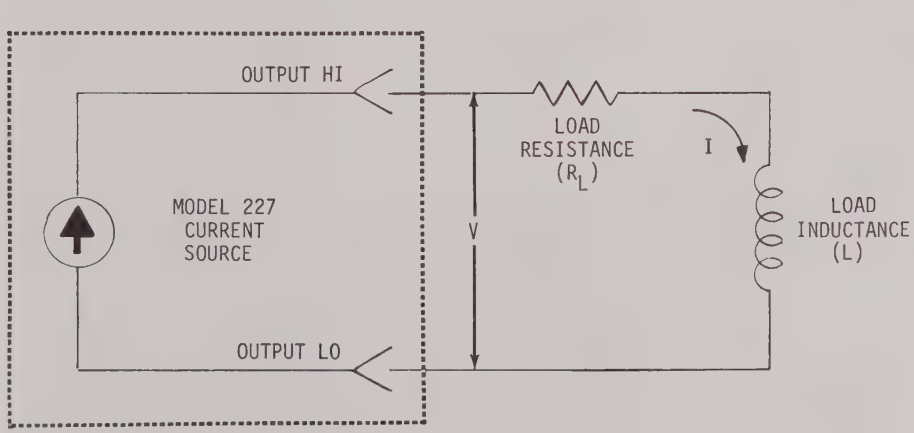
TABLE 3-3.
Output Resistance for Model 227.

Range	Output Resistance
1000 µA	$6 \times 10^{8}\Omega$
10 mA	$6 \times 10^{7}\Omega$
100 mA	$6 \times 10^{6}\Omega$
1000 mA	$1 \times 10^{6}\Omega$



FOR CAPACITIVE LOAD MODEL 227 WILL DELIVER DIALED CURRENT UNTIL COMPLIANCE VOLTAGE V_c IS REACHED

FIGURE 12. Connections as a Current Source with Capacitive Load.



FOR INDUCTIVE LOAD MODEL 227 WILL DELIVER DIALED CURRENT UP TO COMPLIANCE VOLTAGE

FIGURE 13. Connections as a Current Source with Inductive Load.

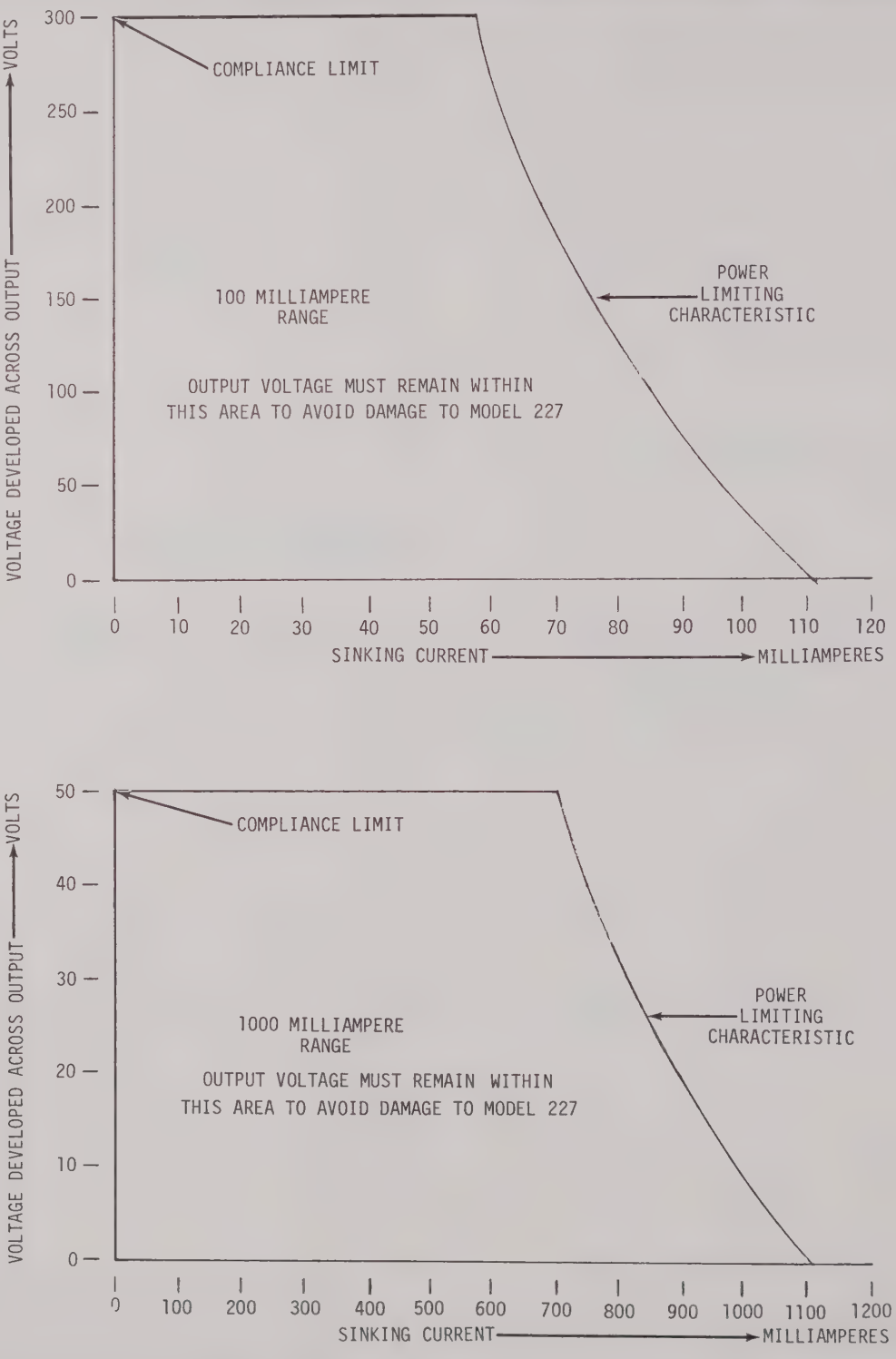


FIGURE 14a,b. Power Limits When Used as a Current Sink.

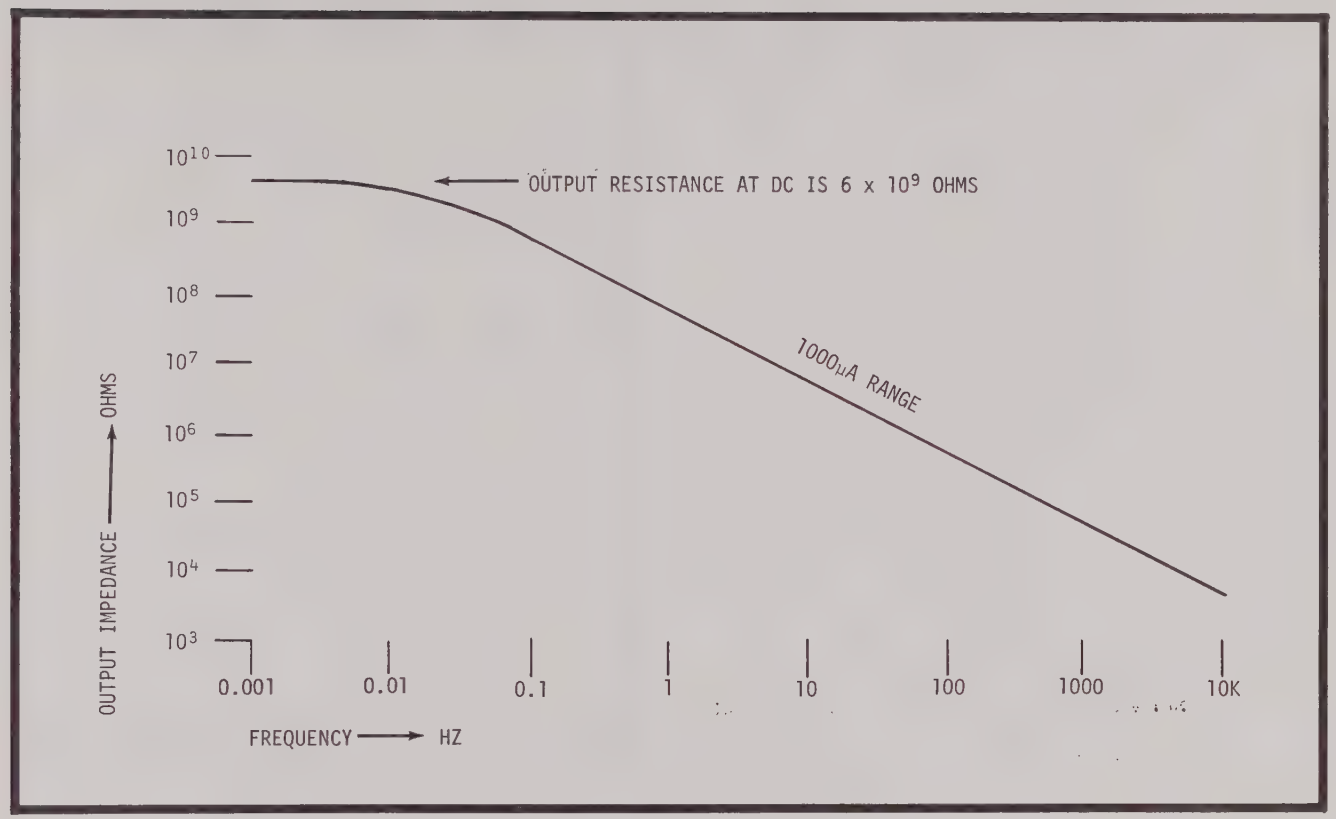


FIGURE 15. Typical Output Impedance Versus Frequency For 1000μA Range.

2. AC Output Impedance. The output impedance of the current source can be considered a shunt capacity across the dc output resistance.

TABLE 3-4.
Output Capacitance

Range	C
1000 μA	400 pF
10 mA	0.003 μF
100 mA	0.03 μF
1000 mA	0.3 μF

Typical values of output impedance versus frequency for the 1000μA range of the Model 227 are shown in Figure 15.

NOTE

The ac output impedance should be considered when using the Model 227 as an amplifier since the loading error will be a function of frequency of the signal generator. For example, if the load resistance is 300kΩ, the loading error at 10 Hz will be approximately 10%.

f. How to Determine Output Noise. The Model 227 output noise is composed of two components: line frequency ripple (120/100 Hz) and high frequency noise.

1. Line Frequency Ripple. This noise is essentially a constant percentage of range.

2. High Frequency Noise. This noise is a constant voltage.

The sum of the two components can be plotted versus compliance voltage as shown in Figure 16. The rms of range-current noise as a percent of the Model 227 range can be obtained in two ways. First, the percent noise at a specific compliance voltage can be determined. For example, for a compliance voltage of 5 volts, the percent noise would be 0.07% as read from Figure 16 of 5 volts or 0.0035 volts rms. Secondly, by multiplying the percent noise (0.07%) times the Model 227 range, a resultant current noise can be determined. For example, for a 5 volt compliance and a 1000μA full range, the rms current noise would be 0.07% x 1000μA = 0.7μA. From Figure 16, it is evident that a low compliance voltage high-frequency noise is dominant. At high compliance voltages, line frequency ripple is dominant. If high frequency noise at low compliance voltages is objectional, a filter capacitor may be placed across the load. A typical frequency versus noise plot is shown in Figure 17 for 1 volt compliance. For a given RC the noise as a % of full range can be read directly.

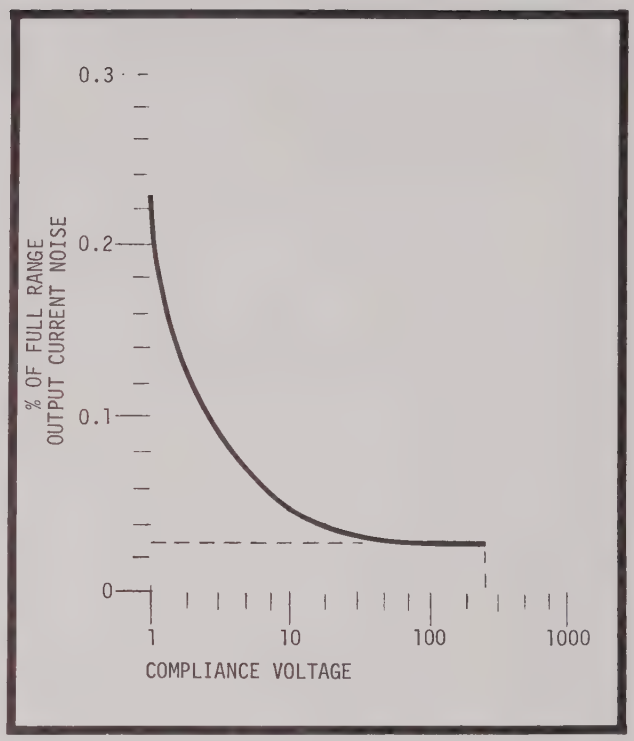


FIGURE 16. Output Noise Versus Compliance Voltage.

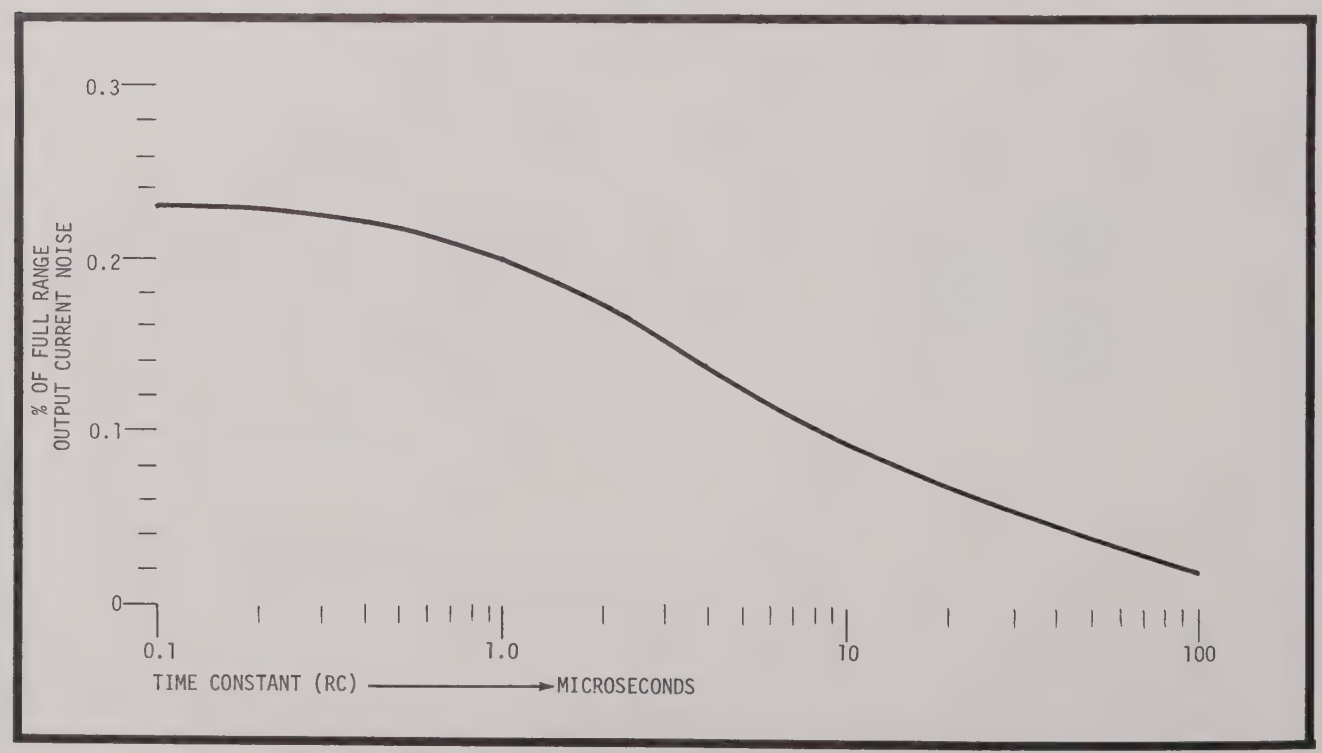


FIGURE 17. Output Noise Versus RC Time Constant of External Load.

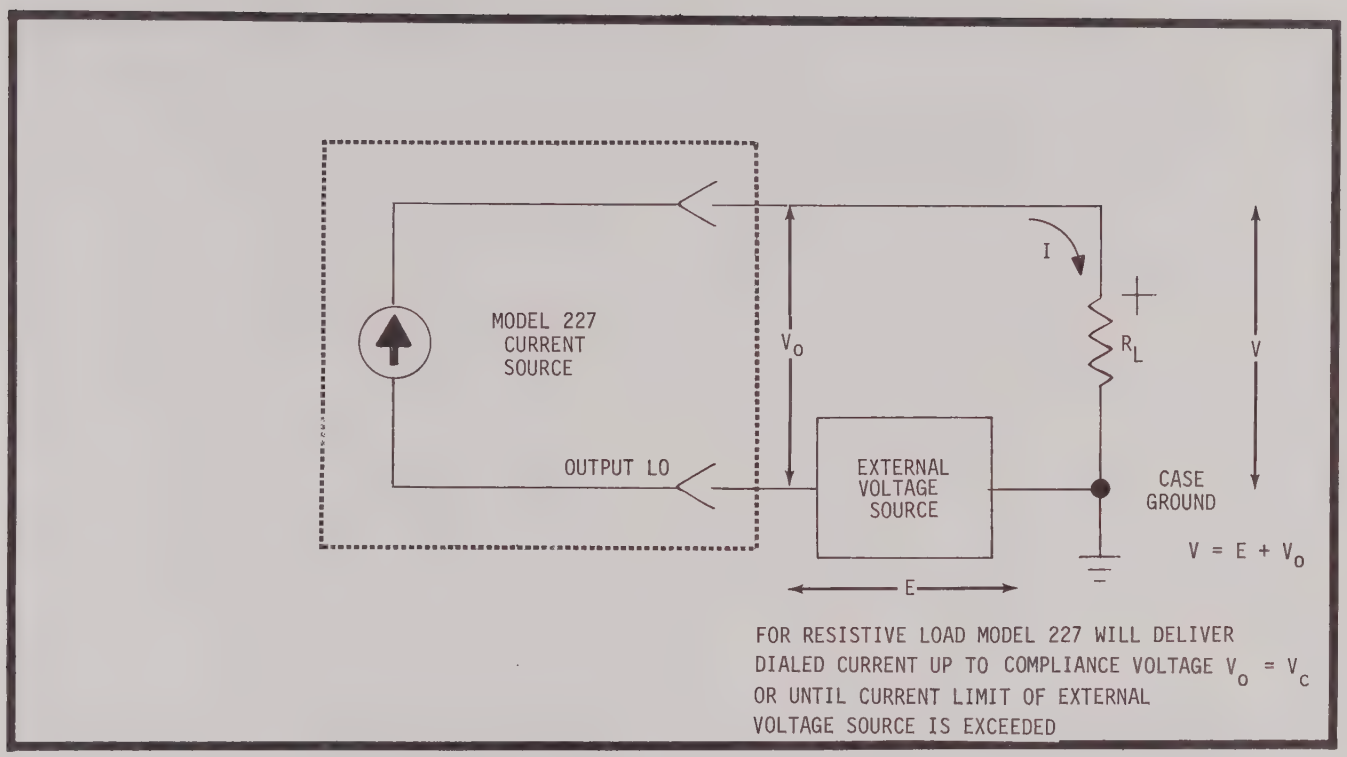


FIGURE 18. Connections for Floating Operation.

3-6. HOW TO FLOAT THE MODEL 227. The Model 227 can be floated up to ±500 volts off chassis ground with less than 5ppm of full range change in output current per volt off ground. For floating operation, the front panel FLOAT/GROUND Switch must be set to FLOAT. A filter capacitor C112 (.02mfd) is connected between the low and ground banana posts to minimize line frequency pickup. The low to ground isolation is approximately 10^7 ohms. See note.

a. Extended Compliance Voltage. A typical example of floating operation is shown in Figure 18. In this example, the Model 227 can be used with a voltage supply such as Keithley Model 240A to extend the maximum compliance voltage to 800 volts. The Model 227 then can be adjusted for a compliance voltage of +200V to +800V or -200V to -800V. Since the maximum current output of the Model 240A is 20 milliamperes, the dialed current on the Model 227 should not exceed this maximum.

b. Precautions when Using an External Voltage Source. When an external voltage source is connected in series with the Model 227 output, care should be taken to observe the power limits shown in Figures 14a and 14b when sinking current. For example, if the external voltage source is capable of delivering 60 milliamperes at 300 volts (or 700mA at 50V), a shorted load could cause the Model 227 to sink current causing excessive power dissipation and possible damage to the Model 227.

NOTE

On some models a shorting link is provided to connect LO and CASE. On models presently manufactured, banana type terminals are used instead of binding post type and the shorting link is no longer used. A front panel FLOAT/GROUND Switch has been added to permit a connection between LO and CASE for grounded applications.

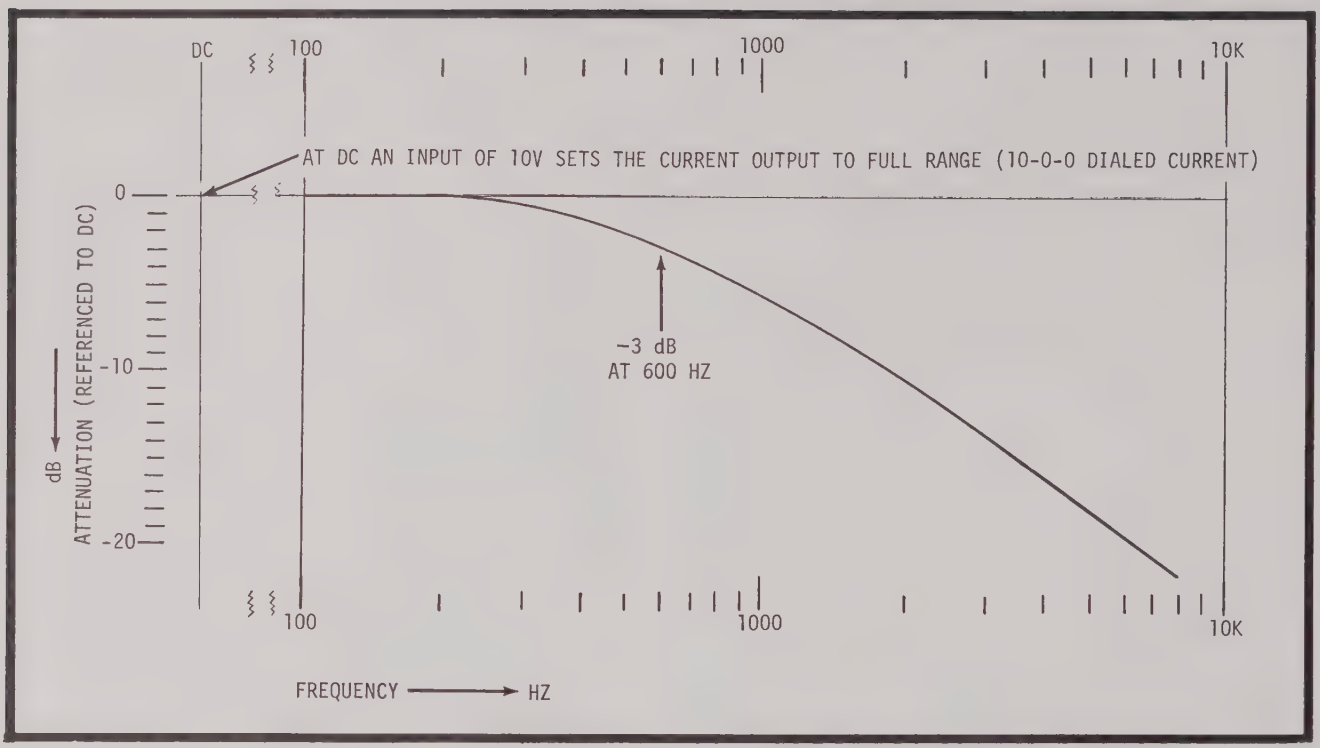


FIGURE 19. Frequency Response for Voltage Programming

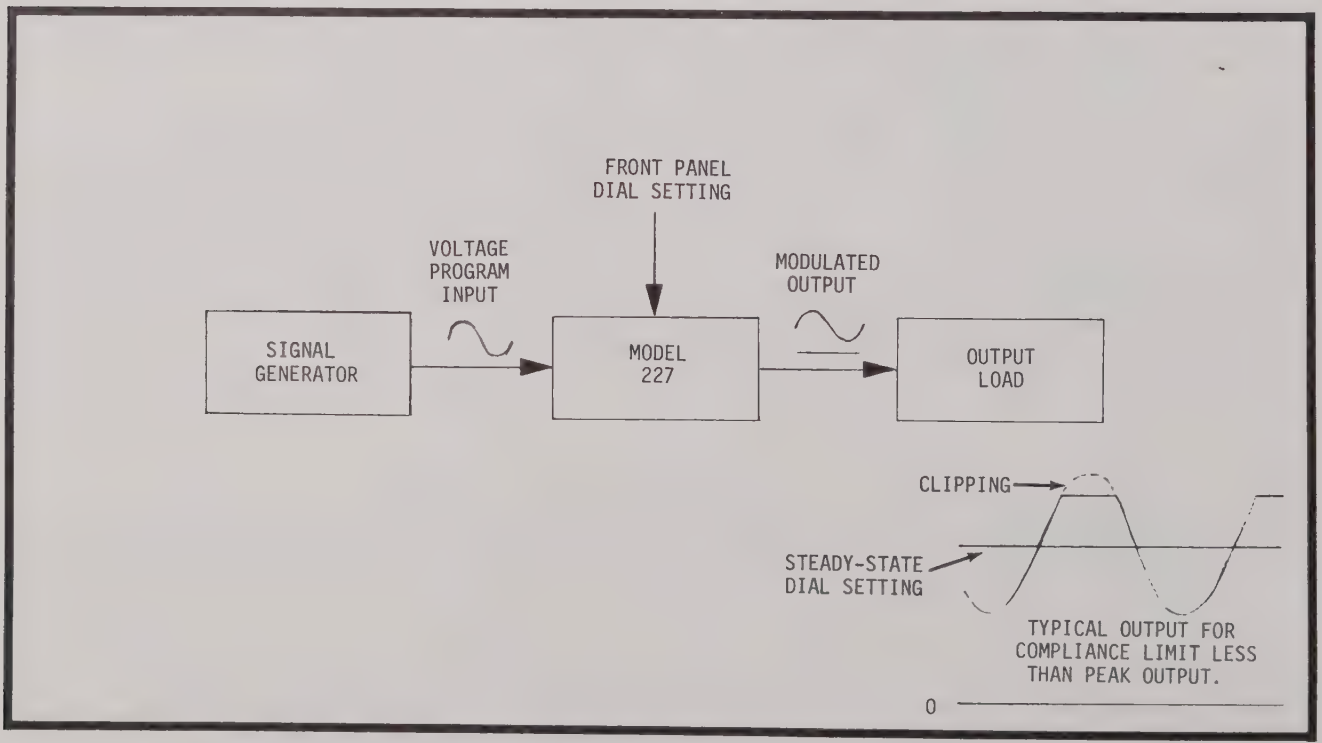


FIGURE 20. Use of Voltage Program Input to Modulate Current.

3-7. HOW TO USE VOLTAGE PROGRAM INPUT. The Model 227 provides a voltage program input (standard) for applications requiring remote current control, or use as a bipolar constant-current amplifier or ac modulated constant-current source. The transfer function for voltage programming is ±10 volts dc for ± full range output. The output current is a sum of voltage programming input and front panel dial settings. Range can be set by the front panel control or the optional Model 2271. The input to the Voltage Programming terminals must be isolated from output load by greater than 10^6 ohms.

NOTE

Voltage programming is also possible in the REMOTE PROGRAM mode. When used in combination with resistance programming, the resultant output is the sum of resistance and voltage programming.

NOTE

Maximum input to voltage program input is ±15V. If an input greater than ±15 volt is applied accidently, the Model 227 output current is internally limited so as not to exceed approximately 180% of full range. Recovery is automatic when the overvoltage is removed.

a. How to Voltage Program or Use as a Bipolar Amplifier. The Voltage Program input is dc-coupled with a bandwidth (-3dB) to 600 Hz minimum. Input resistance is 10 kilohm. An input of ±10V (at dc) sets the output current to ± full range or 10-0-0 dial setting. The transfer function accuracy and offset error can be expressed by the following equation:

$$\% \text{ error (full range)} = \pm(0.5\% \frac{V_{in}}{10} + 0.1\%)$$

The input floats at the output HI voltage and must be isolated by greater than 10^6 ohms. Since Voltage Program input may be floating at up to 300 volts, the signal generator (or dc voltage source) must float at this potential. Figure 19 shows a typical frequency response for the Voltage Program input.

b. How to Use as an AC Modulated Constant-Current Source. The Voltage Program input can also be used in conjunction with the front panel dial settings to provide modulated current outputs.

1. Set the current output (dc level) as described in Section 3-3.

2. Connect Signal Generator to Voltage Program input.

3. Apply modulation signal from Signal Generator.

4. Adjust the % modulation as desired by monitoring the Model 227 output using an ac coupled oscilloscope. Figure 20 shows a typical modulated current output.

NOTE

The Model 227 Compliance Control may be adjusted to suit the measurement. However, if the modulated signal causes the output to exceed the Compliance Limit, then the Model 227 output will be clipped.

TABLE 3-5.
Specifications for Model 2271 Programming Option.

Calibrated at 25°C ± 3°C

RANGE SELECT: Closure* on one of four lines selects range.

CURRENT SET:
- Voltage Programming: Standard feature of Model 227. See specifications of 227.
- Resistance Programming: Transfer function: 10% of full range per kilohm (±0.5%). Zero at approximately 11 kilohms. Stability: adds ±(0.01% of setting + 0.01% of range)/°C to Model 227 specification. Resistance must be isolated and shielded.

COMPLIANCE LIMIT:
- External Operate: Closure* enables external control of both span and limit. Open enables 227 front-panel control.
- Span Select: Closure* enables compliance limit to be set from 10 to 300 volts, open makes span 4 to 50 volts.
- Compliance Limit Set: Resistance programmed, nonlinear transfer function, 0Ω yields high end of span, 25kΩ yields approximately mid span, open circuit yields low end. Resistance must be isolated and shielded.
- Flag (Output): Logic "0" (≡<0.4V drop while sinking 16mA to external power supply Lo) appears when 227 is in compliance limit. Logic "1" (≡>2.4V at up to 400μA referenced to supply Lo) appears when 227 is not in compliance limit.

REQUIRED CONTROL LEVELS:
- *CLOSURE ≡ Closure to external power supply LO within 0.5 volt while sinking 50mA (range-select for 1-ampere range requires sinking 100mA).
- OPEN ≡ >2 kilohms referenced to external power supply Lo.

EXTERNAL POWER SUPPLY: Requires external power supply of 5 to 6 volts @ 200mA.

CONNECTOR: DAM-15S type mounts on 227 rear panel.

ACCESSORIES SUPPLIED: Mating connector.

TABLE 3-6.
Pin Out for Model 2271 Programming Option.

Pin No.	Functional Description	Level
1	Compliance Setting	RESISTANCE PROGRAM – COMP
2	Current Setting	RESISTANCE PROGRAM – CURRENT
3	Remote Program Low	0V, GUARD
4	+5 Volts Power Supply Input	+5V INPUT
5	Compliance Limit Monitor	LIMIT = LOW
6	10mA Range Set	10mA = LOW
7	1000mA Range Set	1000mA = LOW
8	Compliance Limit	REMOTE COMPLIANCE = LOW
9	Compliance Setting	RESISTANCE PROGRAM – COMP
10	Current Setting	RESISTANCE PROGRAM – CURRENT
11	Remote Program Low	0V, GUARD
12	+5 Volt Common	COMMON
13	1000μA Range Set	1000μA = LOW
14	100mA Range Set	100mA = LOW
15	300V Compliance Set	300V = LOW

3-8. HOW TO USE THE MODEL 2271 PROGRAMMING OPTION.

a. How to Make Connections. When the Model 2271 is installed, a 15-pin connector is furnished on the rear panel as shown in Figure 21. A summary of pin locations is given in Table 3-6.

b. How to Program.

1. Auxiliary +5V Power Supply. The user must furnish an external power supply. The supply must be capable of energizing a relay coil with a nominal 3.9V pull-in voltage (at 20°C). (Temperature coefficient is approximately 0.0133V/°C up to 50°C.) An additional 0.2 volt (1Ω at 200mA) drop should be allowed for wiring plus up to 0.5 volt drop for closure to ground (when the relay coil is energized). As a result, a nominal +5V to +6V power supply should be used depending on the individual measurement circumstances (such as ambient temperature etc.). The external 5 volt supply must be connected between J401 pins 4 (+) and 12 (common).

2. How to Program Compliance.

a). Set front panel compliance to minimum.

b). Determine the required compliance range, either 50V or 300V. If 300V maximum compliance is desired, connect pin 15 to common (pin 12). If 50V maximum compliance is desired, leave pin 15 unconnected.

c). Determine magnitude of compliance desired and select appropriate resistance from either of the following relationships:

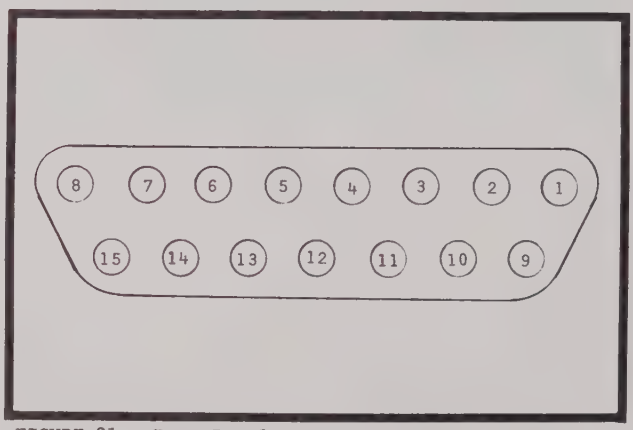


FIGURE 21. Rear Panel Remote Programming Connector.

For the 300V Compliance Range:

$$R_{com}\ (k\Omega) = \frac{7.4 \times 10^3 - 24.3\ E_{com}}{E_{com} - 3.37}$$

For the 50V Compliance Range:

$$R_{com}\ (k\Omega) = \frac{1.24 \times 10^3 - 24.3\ E_{com}}{E_{com} - .56}$$

where R_{com} is the programming resistor and E_{com} is the compliance limit voltage.

d). After the resistance is connected between pins 1 and 9, then connect pin 8 to common to enable the remote compliance control.

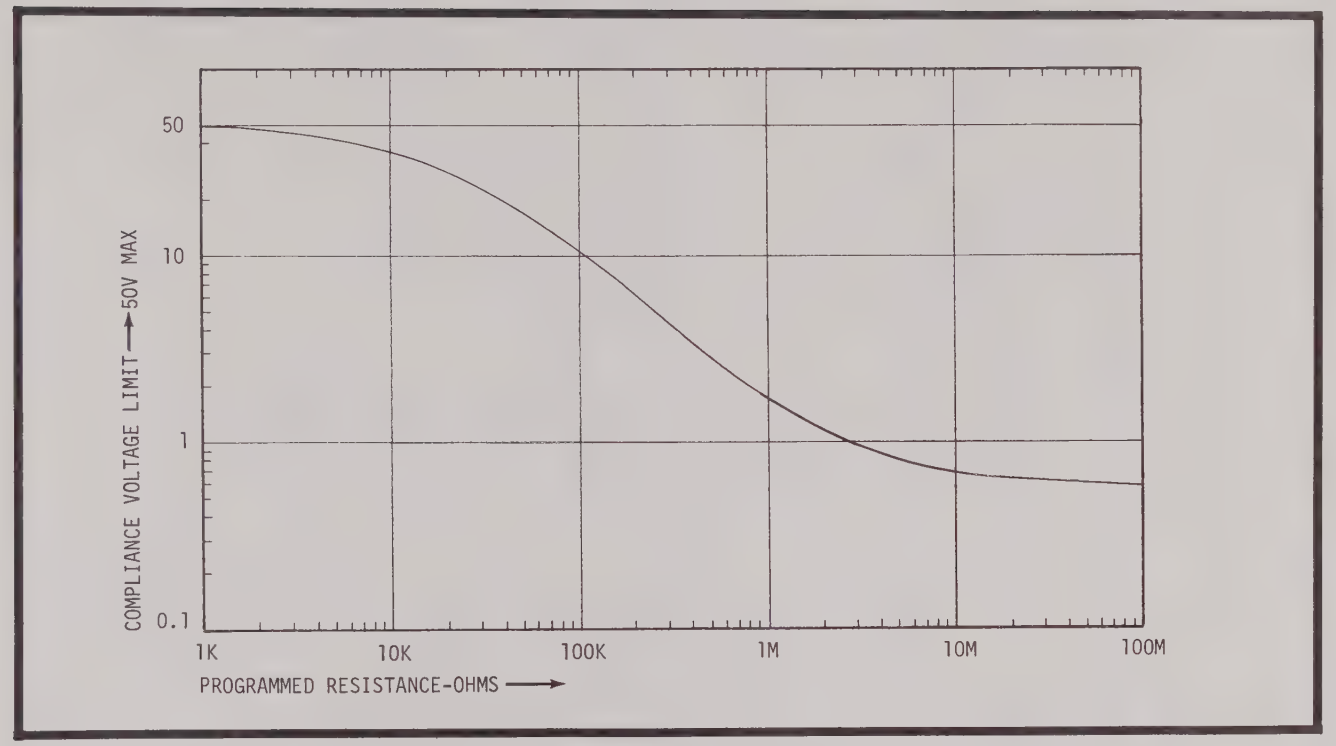


FIGURE 22. Compliance Programming up to 50V.

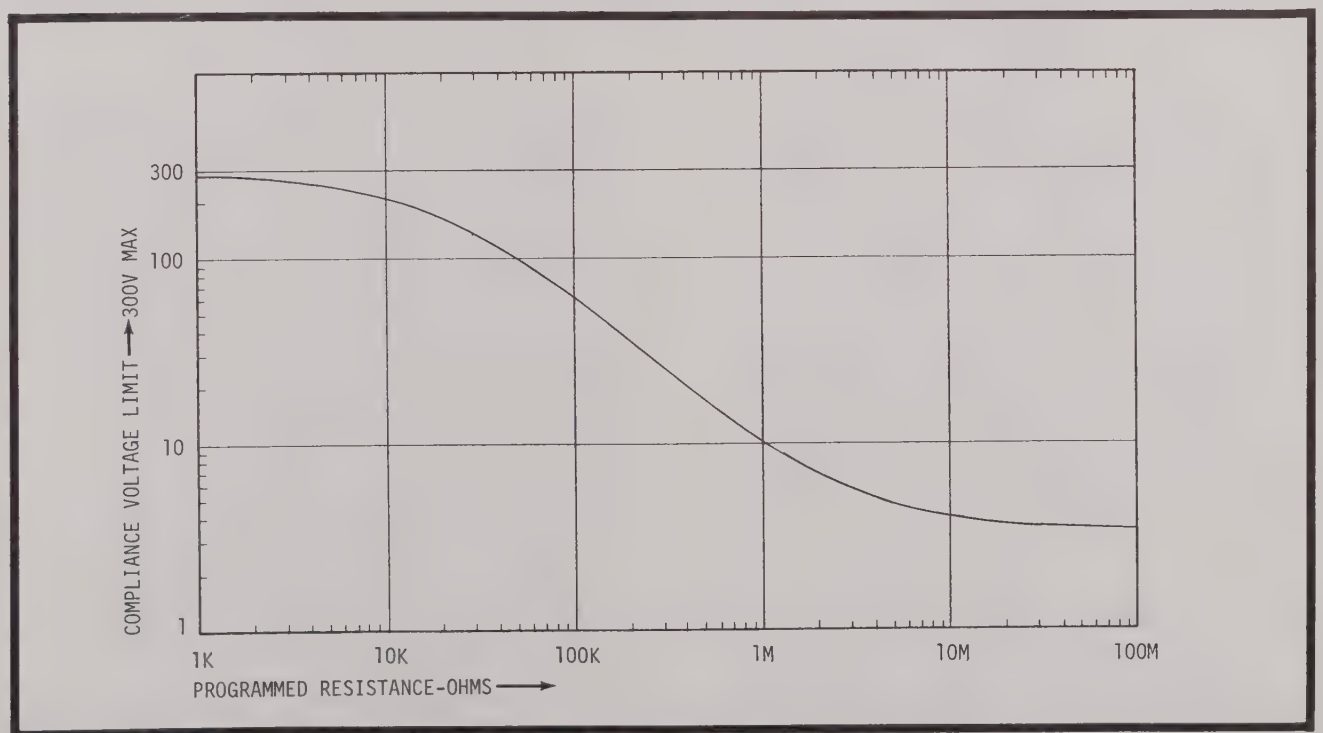


FIGURE 23. Compliance Programming up to 300V.

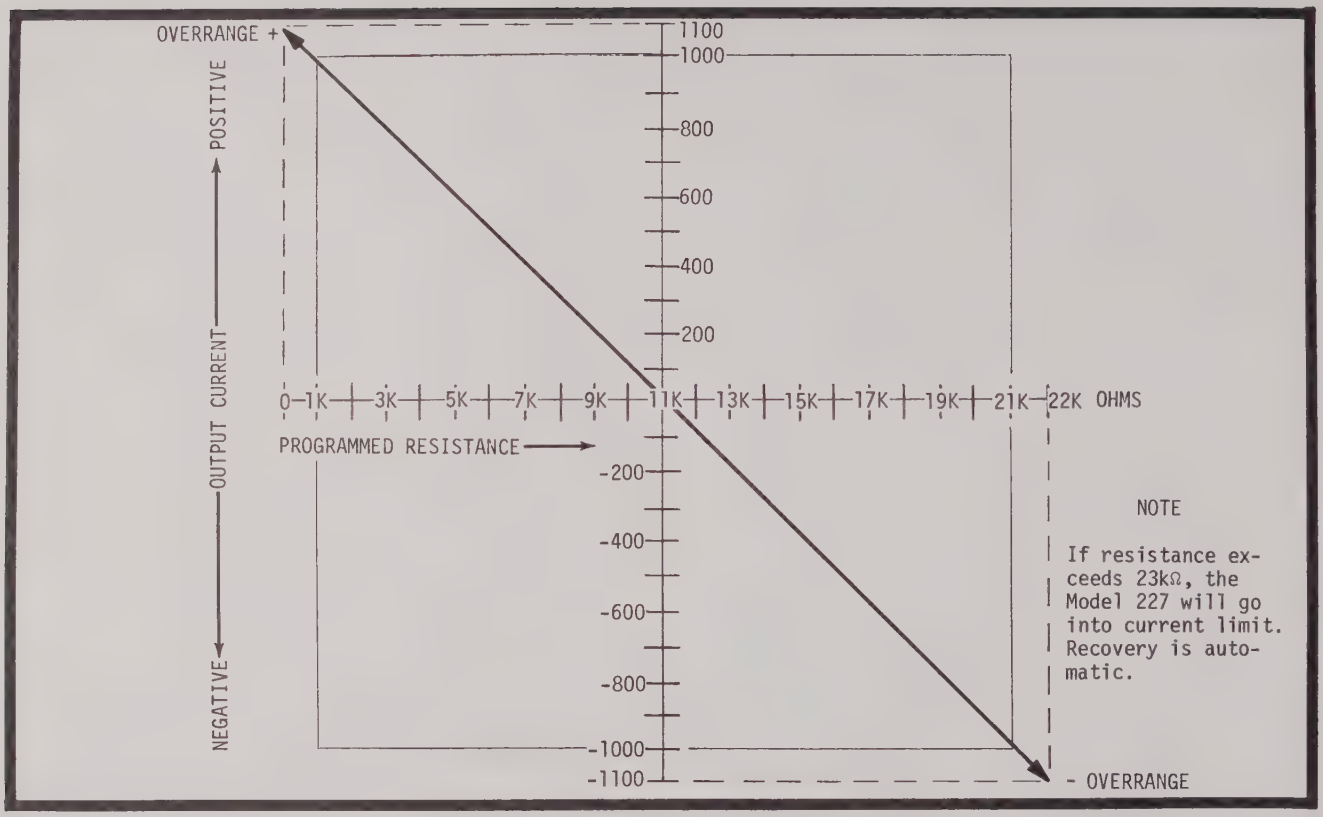


FIGURE 24. Resistance Programming of Current.

IMPORTANT

If pin 8 on the Remote Program connector is not grounded, then the maximum compliance limit will be determined by the front panel Range Switch setting. For example, if the Range Switch is set to 10 milliampere and the current range is set remotely on the 10 milliampere range (pin 6 grounded), then the maximum compliance voltage would be approximately 300 volts. However, if the current range is set remotely on the 1000 milliampere range (pin 7 grounded), then the maximum compliance voltage would be approximately 90 volts rather than the 50 volts given in the specifications. As a result, the current output would not have guaranteed regulation for compliance voltages between 50 and 90 volts on the 1000 milliampere range.

NOTE

When in external compliance (pin 8 = common), it is possible to select 300V maximum on the 1 amp range which will result in compliance voltages up to 90V. Above 50V compliance voltage, the Model 227 may have excess noise and poor stability, and for this reason, the 50V maximum compliance should be selected when on 1000mA range.

3. How to Use Compliance Limit Monitor. This output allows the user to monitor whether or not the Model 227 is in voltage limit mode. When the compliance limit is reached, the front panel LIMIT lamp will turn on and pin 5 on J401 will be in low state. When LIMIT is "ON", pin 5 will sink up to 16m with no more than 0.4V drop. When the LIMIT is "OFF" the high state depends on the voltage level of the user-furnished 5V power source (greater than 2.4V).

4. How to Program the Current Control (Resistance Programming). The magnitude of the current output is a function of the resistance connected between pins 2 and 10 on J401. The transfer function is given by the following equation:

$$I_o = (1.1 - R_p \times 10^{-4}) \times \text{Full Range}$$

where R_p = resistance in ohms
I_o = current in same units as range.

also $$R = \left(1.1 - \frac{I_o}{\text{Full Range Current}}\right) \times 10^4$$

NOTE

Set Polarity switch to "+" to assure rated accuracy. Output accuracy for resistance programming can be expressed as a % of full range output as follows:

$$\%\ \text{accuracy (full range)} = \pm\left(0.5\%\ \left[\frac{R_p - 11)}{10}\right] + 0.12\%\right)$$

where R_p = resistance in kilohms ($10^3\Omega$).

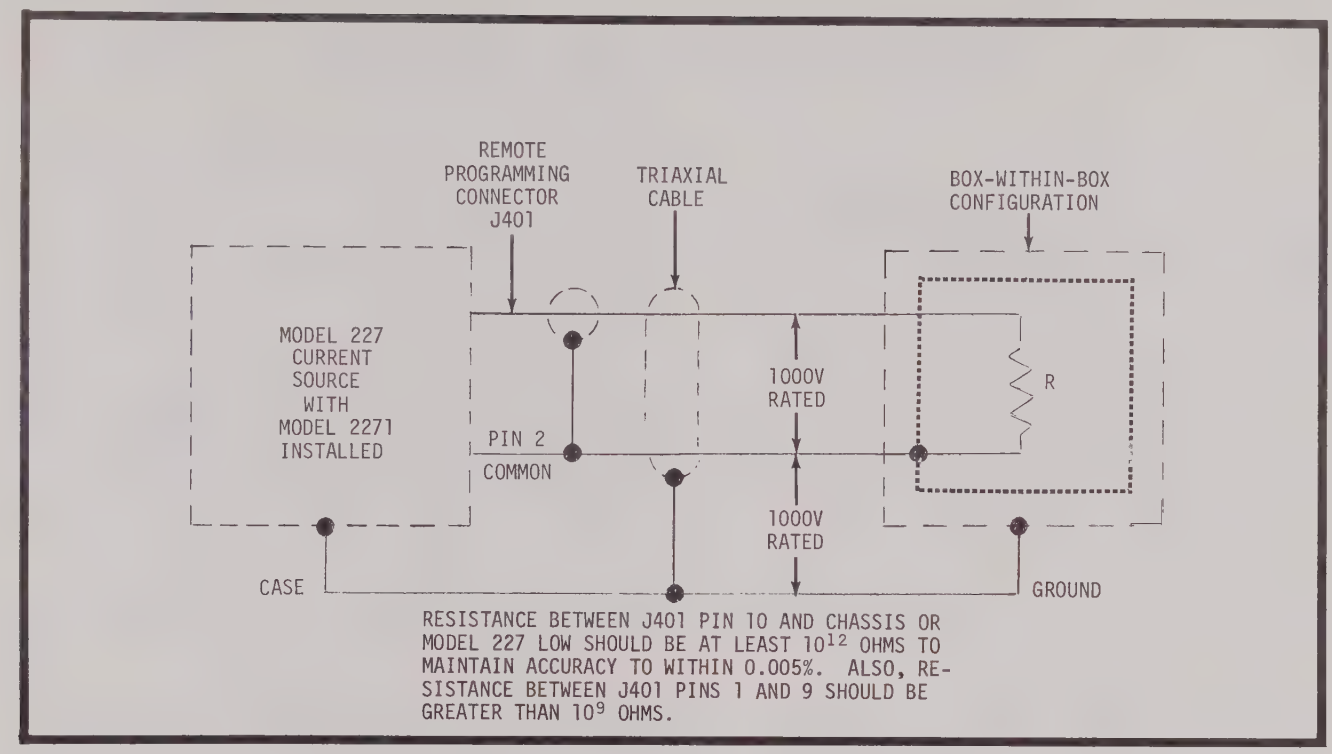

REMOTE PROGRAMMING CONNECTOR J401
TRIAXIAL CABLE
BOX-WITHIN-BOX CONFIGURATION
MODEL 227 CURRENT SOURCE WITH MODEL 2271 INSTALLED
PIN 2
COMMON
1000V RATED
1000V RATED
R
CASE
GROUND
RESISTANCE BETWEEN J401 PIN 10 AND CHASSIS OR MODEL 227 LOW SHOULD BE AT LEAST 10^{12} OHMS TO MAINTAIN ACCURACY TO WITHIN 0.005%. ALSO, RESISTANCE BETWEEN J401 PINS 1 AND 9 SHOULD BE GREATER THAN 10^{9} OHMS.

FIGURE 25. Preferred Cabling Techniques.

For example, for full range output R_p = 21kΩ, and % accuracy equals the following:

$$\% \text{ accuracy} = \pm(0.5\% \ [\frac{21 - 11}{10}] + 0.12\%)$$

$$= \pm 0.62\% \text{ (of full range)}$$

5. How to Program Range. Range can be set to any of the four ranges by grounding the appropriate line as shown in Table 3-7. To use the Model 2271, set the Range switch to REMOTE PROGRAM.

TABLE 3-7.
Remote Range Selection.

Range Desired	Condition of Lines Pin 6	Pin 7	Pin 13	Pin 14
1 mA	OPEN	OPEN	GND	OPEN
10 mA	GND	OPEN	OPEN	OPEN
100 mA	OPEN	OPEN	OPEN	GND
1000 mA	OPEN	GND	OPEN	OPEN

NOTE

When range changing, if all four pins are open simultaneously, the Model 227 will not have a current output (output terminals are open). To avoid relay arcing either program the current back to zero or make-before-break the connections to the range lines when changing range. If more than one pin is closed, the higher current range is enabled. For example, if all four pins are closed to ground, the 1000mA range is selected. Typical pull-in time for all relays is 30 milliseconds. Typical release time is 10 milliseconds.

NOTE

The temperature coefficient of the Model 2271 adds ±(0.01% of setting/°C + 0.01% of range/°C) to the Model 227 Specifications. Thus the total Model 227/2271 coefficient could be expressed as ±(±0.015% of setting/°C + 0.015% of range/°C). For remote programming, the temperature coefficient can be expressed as follows:

$$\%\text{T.C. (full range)} = \pm(0.015 \ [\frac{R_p - 11}{10}] + 0.015)/°\text{C}.$$

For example, at a full range setting, the t.c. = ±0.03%/°C.

6. Preferred Cabling Techniques. Since the Model 227 could be affected by excessive cable capacity, a triaxial cable (shield within a shield) should be used with the inner shield connected to pin 2 on J401, and the outer shield connected to CASE. Insulation between shields should be rated at 1000 volts especially for floating applications. Box-within-a-box construction should be used for all circuitry used in resistance programming.

NOTE

The maximum allowable capacitance between J401 pins 1 or 10 and chassis is 300pF unless compensating capacitance Cp is installed across the current programming resistor Rp as follows:

$$Cp = [\frac{R_L}{R_p} C - 1 \times 10^{-7}] \text{ where } R_L = \text{load resistance}$$

SECTION 4. ACCESSORIES

Model 1008 Single Rack Mounting Kit.

Applications: The Model 1008 adapts Keithley Style "N" instruments for 5-1/4 in. x 19 in. mounting with 11 in. depth behind front panel. The kit is also useable with 14 in. depth instruments.

Parts List:

Item No.	Description	Qty.	Keithley Part No.
1	Half Rack Panel	1	25815B
2	Bracket Angle	1	26757C
3	Bracket Angle	1	26794C
4	Phillips Screws (5/8")	6	#8-32
5	Phillips Screws (1/2")	4	#6-32
6	Socket Screws (3/8")	2	#10-32
7	Phillips Screws (5/8")	4	#6-32
8	Kep Nut, #6-32	4	#6-32

Assembly Instructions:

1. Secure Half Rack Panel (Item 1) to Bracket Angle (Item 2) using two socket screws (Item 6).

2. Remove Side Dress Panels (left and right) from instrument.

3. Secure Bracket Angles (left and right) to instrument. (Half Rack Panel may be located on the left or right to suit mounting requirements.) Use Phillips Screws (Items 4 and 5) as shown in Figure 26 for 14 in. depth instruments. Use longer screw (Item 7) and Kep nut (Item 8) for 11 in. depth instruments.

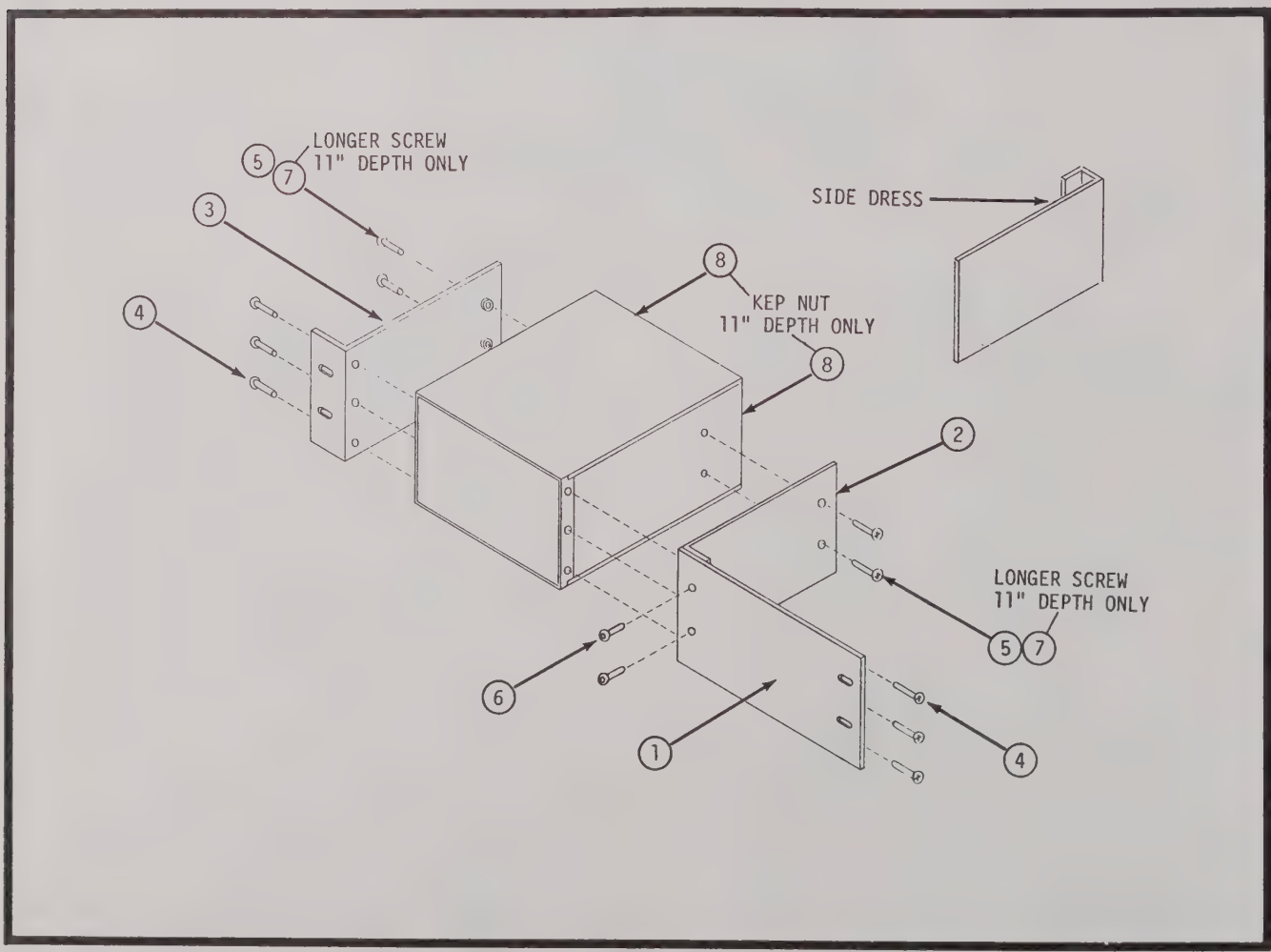


FIGURE 26. Model 1008 Single Rack Mounting Kit.

SECTION 5. THEORY OF OPERATION

5-1. GENERAL. This section contains information to describe the Model 227 and Model 2271 circuit operation.

5-2. CURRENT SOURCE CIRCUITRY.

a. Basic Power Supplies. (See schematic 26227D.)

1. Transformer Connections. Line power is applied to the Model 227 via a 3-wire line cord (P306). Power switch S301 disconnects one side of line. Fuse F301 protects the Model 227 from over-current. Line switches S302 and S303 connect to tapped, primary windings on transformer T301 to suit the line voltage available. (See Specifications.)

2. Fan Connections. The fan (B301) is connected to T301 primary windings ORN and BLK. The connection is made such that a nominal 117 volts is always applied to the fan. When the Model 227 is set for "LO" line operation (90 to 110 volts), transformer T301 steps up the voltage (auto-transformer action) to a nominal 117 volts.

3. Low Voltage Supplies.

a). ±12V (VS Supply). This supply is powered by center-tapped secondary windings (GRN - YEL/GRN-GRN). Diodes CR306 and CR307 provide a full-wave rectified voltage of approximately 30 volts. Integrated circuit U302 is a series-regulator which provides an output of +12 volts referenced to "OVS". Resistors R313 and R314 form a voltage divider. Integrated circuit U304 is a unity-gain amplifier which regulates "OVS" with respect to -12 volts (-12VS). Output transistors Q306 to Q310 increase the current drive capability of U304.

b). ±12V (VD Supply). This supply is powered by secondary windings YEL-YEL. The secondary voltage is half-wave rectified by diode CR305. Integrated circuit U301 is a series-regulator which provides an output of +12 volts referenced to "OVD". Amplifier U303 provides similarly to U302 as described in paragraph a) above.

4. High Voltage Supplies. These supplies include an unregulated 86 volt supply and a unregulated 340 volt supply which is "piggy-backed" on the 86 volt supply which when regulated together, give a net output of approximately 325 volts.

a). +86 Volt Supply. This supply is powered by secondary windings BLU-BLU. The secondary voltage is full-wave rectified by diode CR304.

b). +325 Volt Supply. This supply is powered by secondary windings RED-RED and BLU-BLU. The secondary voltage is full-wave rectified by diode bridge CR302. Divider network (R305, R306, and R307) senses the +325 output and compares it to the zener diode reference (CR303, R309). The error voltage developed by differential amplifier Q304 and Q305 is applied to driver transistor Q301 and output transistor Q302. Resistor R304 is used to sense the current output of the 325V supply. The voltage developed across R304 is applied to Q303 via divider R301 and R310. If the output current of the 325V supply increases beyond approximately 180mA, transistor Q303 conducts and turns off transistor Q301. Hence, the output voltage of Q302 is decreased, causing a fold-back current limiting action. When fold-back occurs, the current is reduced to approximately 30 to 40mA at an output of approximately 86 volts. If over-current is present for greater than 1.5 milliseconds, full fold-back occurs. In normal operation, the Model 227 should not experience an over-current condition beyond 500 microseconds, so that recovery is automatic. A temporary overload condition can occur when the Model 227 output is shorted (either by use of OUTPUT SELECTOR switch or direct connection at the output terminals).

c). Thermal Breaker. This thermal circuit-breaker (TK301) protects the Model 227 in the event of excessive temperative rise. The breaker is designed to open at approximately 185°F.

b. Reference Amplifier Circuitry. The output of this circuitry provides a stable ±1V reference voltage for the current source regulator. Integrated circuits U102 and U103 are summing amplifiers. The zener reference (CR110) is switched by Polarity Switch S105 to provide either ±6.2V at the input of U103 (via resistors R148, R128, and R129). Feedback resistors R150, R114, R115, R116, R130, R125, R126, and R127 are selected by use of Decade Switches S102 and S103. The output of U103 is varied from 0V to ±4V (where 4V = full range [10-0-0 dial setting]). Potentiometer R129 is a calibration adjustment which adjusts the gain of U103. The output of U103 is applied to U102 through summing resistor R121. (Voltage programming is summed through R122 and R123. Capacitor C106 filters the voltage programming input to prevent slew-rate limiting.) The gain of U102 is set by resistors R121 and R119 to provide a net gain of 0.25 or an output of 1 volt for full range (10-0-0).

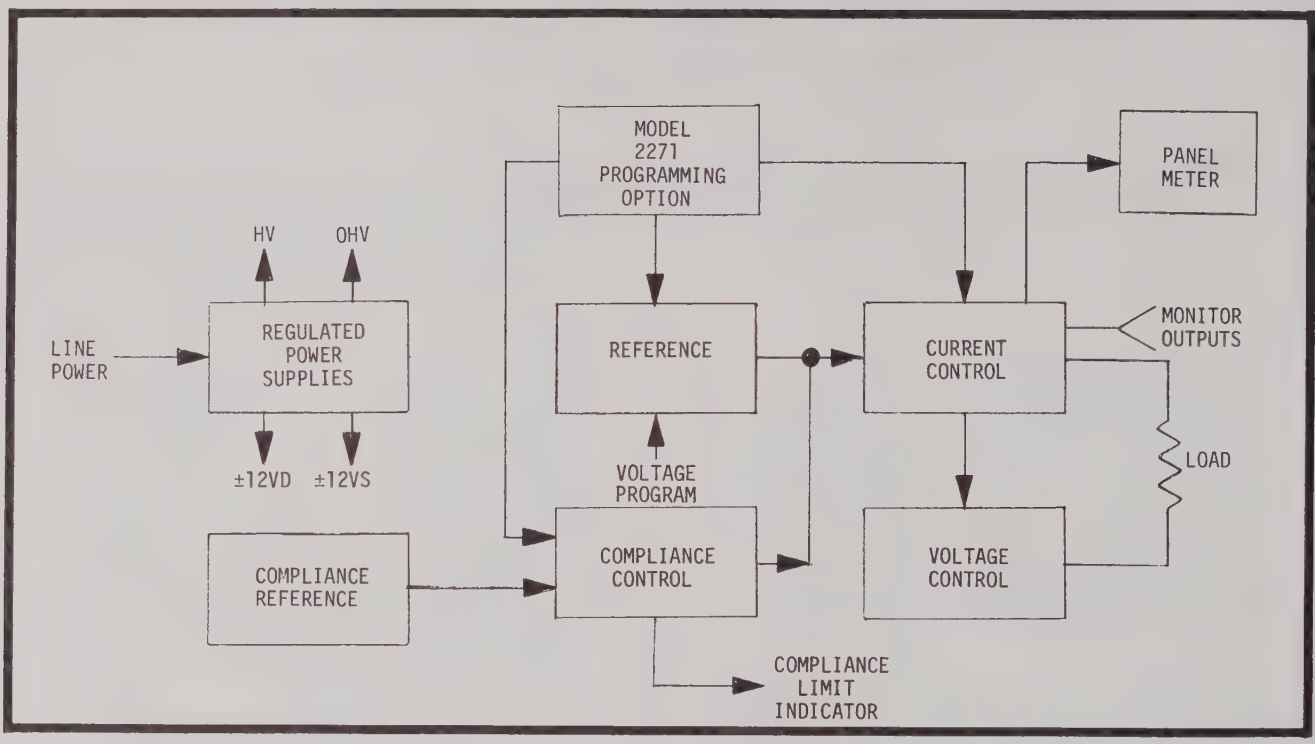


FIGURE 27. Overall Block Diagram of Model 227.

c. Bridge Current Source. This circuit is a bridge-configuration regulator. Integrated circuit U205 and associated circuitry maintains the current output to the dialed setting. The output current is regulated by comparing the voltage drop across the range resistor (R215, R216, R215, and R218) to the reference amplifier output (U102, pin 6). Any difference voltage causes an output at U205 pin 6 which drives output stages Q201 through Q208. A positive output current flows out of the HI terminal, through the load, and into a unity gain inverting amplifier made up of U206 and output stage composed of Q209 and Q212. The action of the bridge output causes the voltage across the load to be split evenly between the current source and the unity gain inverting amplifier. This configuration permits a voltage swing from +300 volts to -300 volts, using a single 300 volt supply.

d. Compliance Control Circuitry. This circuitry controls the maximum compliance voltage which can be developed on a given range.

1. Compliance Reference. Transistor Q101 and zener diode CR101 form a reference source which provides a constant-current through potentiometer R101, the front panel VOLTAGE COMPLIANCE control. The voltage developed across R101 is 9.12V on 1000µA, 10mA, and 100mA ranges; and 1.64V on 1000mA range.

2. Compliance Limit Circuitry. The reference voltage is applied to integrated circuit U201, a unity-gain; non-inverting amplifier. The output of U201 drives U202, an inverting, summing amplifier. The outputs of U201 and U202 are equal and opposite polarity. These outputs are applied to U203 and U204, differential transconductance amplifiers. (Differential transconductance amplifiers provide an output current proportional to the difference voltage at the input.) The reference voltage is compared at the transconductance amplifier inputs to divider outputs (R201, R202, R207, and R208) which sense the voltage across the Model 227 output terminals. When the output voltage of the Model 227 reaches the Compliance Voltage Limit (pre-set on the front panel or via the Model 2271), any further increase in voltage causes the transconductance amplifiers to "sink" or "source" current through R117 and R213 via gating diodes CR111 (6-11, and 16-1), thus cancelling out the voltage ap plied to U205. The COMPLIANCE LIMIT Indicator DS104 is controlled by U101E and U101B. When both U101C and Q102 turn off (for limiting condition), the acti causes the COMPLIANCE LIMIT Indicator to be lighted.

e. Miscellaneous Circuitry.

1. Decimal Point Indicators. Indicators DS101, DS102, and DS103 are driven as part of the differential amplifier (U101A, U101B) from the "-12VS" and are selected by contacts on Range Switch S101.

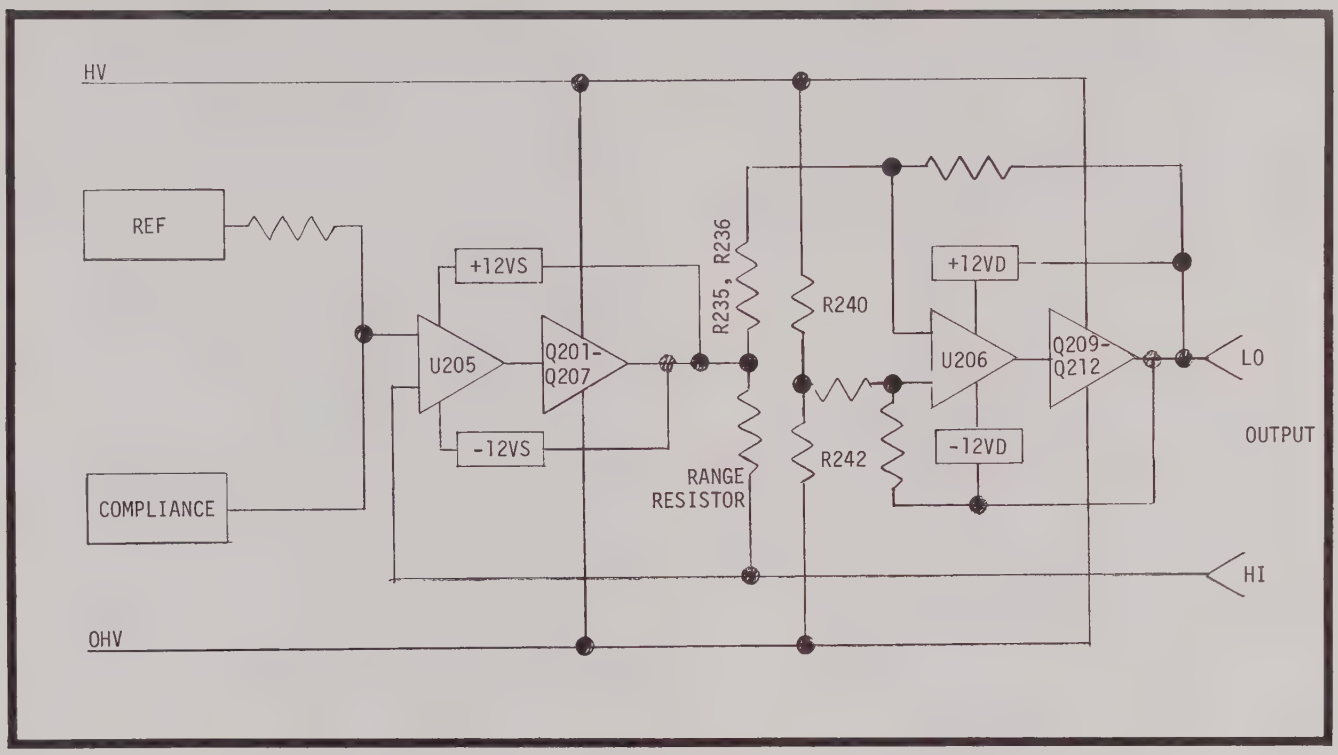


FIGURE 28. Simplified Diagram of Current Source.

2. Output Selector Switch (S104). This switch disconnects the output terminals from the current source. See Operating Instructions, Section 3 for a discussion of switching.

3. Volts Monitor Circuit. This output is provided by integrated circuit U104, a unity-gain, non-inverting amplifier. This circuit buffers the voltage developed at the output so that no loading error can result at HI and LO output terminals. The output of Volts Monitor is the same potential as Output HI and LO (up to 305 volts). Since R143 and R144 provide source resistance of 10 kilohms, loading of Volts Monitor should be taken in consideration.

4. Current Monitor Circuit. This output provides -1 volt (Vcm) for a + full range (10-0-0). Fuse F101 protects this output against accidental short circuits. This voltage is developed between the buffered output of U104 and "OVSR".

5. Meter Circuit. Meter M101 is driven from the output of U104.

a). Voltage Reading. When switch S106 is set to "V", the meter is connected between U104 output and output LO. The meter movement is for full range reading. When Switch S107 is set to X1, the current developed through M101 is a function of R133, R145, R146, R147, and R_M, where:

$$I_M \cong V_{OUT} \div \left(R133 + R_M + \frac{(R145 + R146)\ R147}{R145 + R146 + R147}\right)$$

When switch S107 is set to X10, the current developed through M101 is a function of R133, R149, R147, and R_M, where:

$$I_M = V_{OUT} \div (R_M + R133 + R147 + R149)$$

b). Current Reading. When Switch S106 is set to "A", the meter is connected between U104 output and "OVS". When Switch S107 is set to X1, the current developed through M101 is a function of R133 and R_M where:

$$I_M + V_{CM} \div (R_M + R133)$$

When Switch S107 is set to X10, the current developed through M101 is a function of R133, R149, and R_M where:

$$I_M + V_{CM} \div (R_M + R133 + R149)$$

6. Power ON/OFF Transient Suppression Circuit. This circuit (located on board PC-396) minimizes the effect of power surge when power to the Model 227 is applied or removed.

5-3. PROGRAMMING OPTION (MODEL 2271).

a. Range Programming. Range selection is accomplished by energizing relays, (by closure to ground or through a saturated transistor). Relay coils K401, K402, K403, K404, and K405 are connected to the users external +5 volt supply (J401, pin 4). Closure to ground at J401 pins 6, 7, 13, or 14 energizes the relay coils. If the 1000mA range is selected, relay K405 transfers the output stage from 325 volt supply to 86 volt supply. The user +5 volt supply is switched by relay K408 which is energized when the range switch is set to REMOTE.

b. External Compliance. Closure to ground at J401, pin 8 enables external control. When energized relay K407 selects the External Compliance mode.

c. Compliance Span. Closure to ground at J401, pin 15 energizes relay K406. When energized, K406 sets the maximum compliance limit to 300 volts. Contacts K406A set the compliance reference voltage to 9.12 volts maximum. Contacts K406B change the supply voltage at the output stage from 86 volts to 325 volts.

d. Current Setting. (Resistance Programming). Integrated circuits U402 and U401 and zener diode CR409 form a 100 microampere reference current source. The current source drives the external programming resistor connected between J401, pins 2 and 10. The voltage across the programming resistor (at the output of U401, pin 6) is fed to summing amplifier U403 via resistor R426. Diode CR409 and summing resistors R411 and R412 form the reference voltage. As a result, the output of U403 is as follows:

$$V_o = (R_p \times 100\mu A) - 1.1 \text{ volts}$$

(See Section 3-8b4 for further discussion of this transfer function.) Clamping diodes DS401 and DS402 prevent the output of U403 from going to far negative and enable FET switch Q402 to turn full off. Transistors Q406, Q405, and Q407 are for overload protection. FET Switch Q402 is driven by both U406 and Q401. When the Model 227 is switched out of "REMOTE PROG", (Range Switch S101) transistor Q401 turns off. Transistor Q403 turns on, turning off FET Switch Q402, and as a result, disconnects the remote program reference voltage from the Model 227. If the reference voltage at pin 6 of U903 goes above approximately 1.2 volts, U406 turns on Q403 which turns off Q402 disabling the remote program reference to Model 227 causing the output to go to approximately zero.

e. Compliance Limit Programming. Integrated circuit U404 is a summing amplifier. Reference zener diode develops a current through summing resistors R405, R415, and R417 and program resistor (J401 pins 1 and 9). Diode CR414 is a protection device. When relay K406 is energized, the 9.1 volt reference voltage is selected by connecting the proper gain at U404.

f. Compliance Limit (FLAG). Transistor Q404 (NPN) is connected collector to emitter between J401 pins 5 and 12. When the Model 227 goes into compliance limit phototransistor U405 turns off, causing transistor Q404 to saturate (low state).

NOTE

Should it be necessary to remove the Model 2271 Option from the Model 227 chassis, connector J206A, furnished with each 227/2271 (shown on schematic 26226E) must be installed at P206. Connector J206A is a ten-pin Berg Connector with jumper wires between pins A and C; D and G.

SECTION 6. MAINTENANCE

6-1. GENERAL. This section contains information necessary to maintain the instrument. Included are procedures for electrical Performance Checks, Calibration, Troubleshooting.

6-2. REQUIRED TEST EQUIPMENT. Recommended test equipment for checking and maintaining the instrument is given in Table 6-1. Test equipment other than recommended may be substituted if specifications equal or exceed the stated characteristics.

6-3. PERFORMANCE VERIFICATION. Use the following procedures to verify proper operation of the instrument. All measurements should be made at ambient temperature of approximately 25°C ± 3°C and relative humidity below 60%. If the instrument is out of specification at any point, perform a complete calibration as given in Paragraph 6-4. For each function that is checked, an additional uncertainty due to temperature coefficient should be considered if the ambient temperature is beyond the temperature range indicated above.

a. Fuse Checks.

1. Check the line fuse (F301) on the rear panel. For nominal 117V line operation, use a 2.5A type 3AG Slo-Blo fuse. For 234V line operation, use a 1.25A type 3AG Slo-Blo fuse.

2. Check the internally installed protection fuse (F101). This fuse is located on circuit board PC-330 near the front panel. Remove the top cover to gain access to the circuit board.

NOTE

If the Line Fuse (F301) is blown or missing, the Model 227 will be inoperable. If the protection fuse (F101) is blown or missing, the Model 227 will be operable, except the rear panel Current Monitor and Voltage Programming terminals.

b. Line Voltage Setting. Set the Line Switches (S302 and S303) in accord with paragraph 2-3 in Section 2.

c. Preliminary Check.

1. Set OUTPUT SELECTOR switch to "SHORT".

2. Set Range Switch to 1000μA.

3. Set Decade Switches to 10-0-0.

4. Set Polarity Switch to "+".

5. Set METER Switches to "X10" and "A".

6. Set VOLTAGE COMPLIANCE to "0" (minimum).

7. Put External short on Model 227.

8. Set Power Switch to "ON".

9. Set OUTPUT SELECTOR to "ON".

10. Set VOLTAGE COMPLIANCE to 10V.

11. Observe Meter (M101) reading. Current reading should be (+) full range.

12. Set Polarity switch to "-".

13. Observe meter (M101) reading. Reading should be (-) full range.

14. Verify Meter readings for Range Settings of ±10, ±100, and ±1000mA.

15. If all ranges are indicated correctly, proceed to normal verification procedure.

IMPORTANT

The Model 227 will not operate properly if either J206B (Used on Model 2271) or J206A are missing. To order an extra connector for J206A, specify Keithley Part No. 27204A.

TABLE 6-1.
Recommended Test Equipment for Performance Verification.

Item	Description	Minimum Specifications	Mfr.	Model
A	Digital Voltmeter	1.00000V ±(0.015% of rng + 0.015% of rdg) $>10^8\Omega$ input Z	Keithley	190
B	Resistance	100Ω ± 0.01%, 0.12W 10ppm/°C 1kΩ ± 0.02%, 0.12W 10ppm/°C 10Ω ± 0.02%, 1W 10ppm/°C 1Ω ± 0.02%, 10W 10ppm/°C	Vishay Vishay	V53-100 V53-1K
C	Voltage Source	0 to ±10Vdc 0.01% of setting ± 0.002% of range tc < 30ppm/°C	Fluke	341B
D	Resistance Box	0 to 22kΩ ± 0.02%	GR	1433G

d. Dial Accuracy Verification.

1. Dial Accuracy (10-0-0).

a). Set Range to 10mA.

b). Set Decade Dials to 10-0-0*.

c). Connect Resistance (B), 100Ω ± 0.01% to output of Model 227.

d). Connect DMM (A) across output of Model 227.

e). Set COMPLIANCE to 10V.

f). Set OUTPUT SELECTOR to "ON".

g). Set Polarity to "+".

h). Verify that voltage reading is 1.00000V ±0.00612V.

i). Set Polarity to "-".

j). Verify that voltage reading is 1.00000V ±0.00612V.

2. Dial Accuracy (0-0-0).

a). Set Decade Dials to 0-0-0*.

b). Set Polarity to "+".

c). Verify that voltage reading is 0.00000 ±0.0012V.

d). Set Polarity to "-".

e). Verify that voltage reading is 0.00000 ±0.0012V.

3. Dial Accuracy (0-10-0).

a). Set Decade Dials to 0-10-0*.

b). Set Polarity to "+".

c). Verify that the voltage reading is 0.10000 ±0.0017V.

d). Set Polarity to "-".

e). Verify that the voltage reading is 0.10000 ±0.0017V.

NOTE

Other dial settings can be checked if desired. Accuracy for all other settings should be checked to allowable voltage error as follows:

$$\pm(0.005 \times \frac{\text{Dialed Current}}{\text{Current Range}} + 0.0012)$$

NOTE*

Least significant digit should be set carefully since dial is a variable control.

NOTE

If a check is made on dial accuracy immediately after a complete recalibration, the dial accuracy should be checked to allowable voltage error as follows:

$$\pm(0.00449 \times \frac{\text{Dialed Current}}{\text{Current Range}} + 0.00064)$$

4. Dial Accuracy (1000μA Range).

a). Set OUTPUT SELECTOR to "SHORT".

b). Set Range to 1000μA.

c). Connect Resistance (B), 1000Ω ± 0.02% to output of Model 227.

d). Perform steps 1d) through 1j) above.

e). Perform steps 2a) through 2e) above.

f). Perform steps 3a) through 3e) above.

5. Dial Accuracy (100mA Range).

a). Set OUTPUT SELECTOR to "SHORT".

b). Set Range to 100mA.

c). Connect Resistance (B), 10Ω ± 0.02% to output of Model 227.

d). Perform steps 1d) through 1j) above.

e). Perform steps 2a) through 2e) above.

f). Perform steps 3a) through 3e) above.

6. Dial Accuracy (1000mA Range).

a). Set OUTPUT SELECTOR to "SHORT".

b). Set Range to 1000mA.

c). Connect Resistance (B), 1Ω ± 0.02% to output of Model 227.

d). Perform steps 1d) through 1j) above.

e). Perform steps 2a) through 2e) above.

f). Perform steps 3a) through 3e) above.

e. Voltage Program Verification (1000μA Range).

1. Set OUTPUT SELECTOR to "SHORT".

2. Set Range to 1000μA.

3. Set Decade Dials to 0-0-0.

4. Connect Resistance (B), 1000Ω ± 0.02% to the Model 227 output.

5. Connect DMM (A) across output of Model 227.

6. Connect Voltage Source (C) to VOLTS PROGRAM input.

NOTE

Make certain that Voltage Source (C) is capable of floating to ±300V. Also make certain no connection is made between the Voltage Source low terminal and chassis (CASE).

7. Set Voltage Source (C) for +10V output.

8. Set OUTPUT SELECTOR to "ON".

9. Verify that reading on DMM (A) is 1.00000V ±0.006V.

10. Set Voltage Source (C) for -10V output.

11. Verify that reading on DMM (A) is 1.00000V ±0.006V.

12. Set Voltage Source (C) for 0 volts output.

13. Verify that reading on DMM (A) is 0.00000V ±0.001V.

NOTE

If desired, other input levels could be checked. Output accuracy should be verified as follows: Allowable Voltage error =

$$\pm(0.005 \times \frac{\text{Voltage Source (C)}}{10} + 0.001)$$

NOTE

If verification is performed immediately after recalibration, then output accuracy should be verified as follows: Allowable Voltage error =

$$\pm(0.00441 \times \frac{\text{Voltage Source (C)}}{10} + 0.001)$$

f. Voltage Program Verification (10mA Range).

1. Set OUTPUT SELECTOR to "SHORT".

2. Set Range to 10mA.

3. Connect Resistance (B), 100Ω ± 0.02% to Model 227 output.

4. Repeat steps e5 through e13

g. Voltage Program Verification (100mA Range).

1. Set OUTPUT SELECTOR to "SHORT".

2. Set Range to 100mA.

3. Connect Resistance (B), 10Ω ± 0.02% to Model 227 output.

4. Repeat steps e5 through e13.

h. Voltage Program Verification (1000mA Range).

1. Set OUTPUT SELECTOR to "SHORT".

2. Set Range to 1000mA.

3. Connect Resistance (B), 1Ω ± 0.02% to Model 227 output.

4. Repeat steps e5 through e13.

i. Verification of Programming Option (Model 2271).

1. Set Range Switch to "REMOTE PROGRAM".

NOTE

To guarantee specification, the Model 2271 calibration should be done with the Model 227 polarity switch in the "+" position.

2. Set OUTPUT SELECTOR to "SHORT".

3. Select the 1000μA range by closure of J401 pin 13 to common.

4. Disable the External Compliance by opening of J401 pin 8 to common.

5. Set voltage compliance to 10V using FRONT PANEL CONTROL.

6. Connect Resistance Box (D) to current programming inputs at J401, pins 2 and 10.

7. Set current for "zero" by applying 11 kilohms using Resistance Box (D).

8. Connect Resistor (B) 1000Ω, 0.01% to Model 227 output.

9. Connect DMM (A) to Model 227 output.

10. Set OUTPUT SELECTOR to "ON".

11. Verify that DMM reading is 0.00000 ± 0.0012V.

12. Set current for "- full range" by applying 21 kilohms using Resistance Box (D).

13. Verify that DMM reading is -1.00000 ± 0.0062V.

14. Set current for "+ full range" by applying 1 kilohm using Resistance Box (D).

15. Verify that DMM reading is +1.00000 ± 0.0062V.

16. Set OUTPUT SELECTOR to "SHORT".

17. Verify other ranges. Select appropriate range by closure to common (pin 12).

Range	Pin Closure
10mA	pin 12 to pin 6
100mA	pin 12 to pin 14
1000mA	pin 12 to pin 7

Repeat steps i7 through i16 for each range selected.

NOTE

Other settings of output current can be checked if desired by using the following accuracy relationship:

Allowable Voltage error =

$$\pm(0.005 \times [\frac{R_p - 11 \times 10^3}{10 \times 10^3}] + 0.0012)$$

where R_p = resistance applied.

If verification is performed immediately after recalibration, the output accuracy should be verified as follows:

Allowable Voltage error =

$$\pm(0.00426 \times [\frac{R_p - 11 \times 10^3}{10 \times 10^3}] + 0.00055)$$

IMPORTANT

When the Model 2271 is to be used with the Model 227, the Model 2271 must be installed prior to calibration of the 227, since the Model 2271 affects the Model 227 calibration. Calibration of the Model 227 should be performed prior to performing the Model 2271 procedure.

NOTE

The recommended recalibration period for the Model 227 is 12 months from factory calibration. If the complete calibration is performed using equipment specified, the Model 227 or Model 227/2271 will be useable for an additional 12 months within published specifications. If repairs are made after initial calibration, the complete calibration procedures should be performed.

5-4. ADJUSTMENT/CALIBRATION PROCEDURE. The following adjustments should be performed when any specification has been determined to be out-of-tolerance. The Performance Check given in paragraph 6-3 should be performed prior to this Calibration Procedure. If any step in the Calibration Procedure cannot be performed properly, refer to the Troubleshooting Procedure (paragraph 6-5) or contact your Keithley representative or the factory. All measurements should be made at ambient temperature of 25°C ± 3°C and relative humidity below 60%.

a. Chassis Assembly. To gain access to the adjustments in the printed circuit boards, remove four screws on Top Cover and Bottom Cover.

CAUTION

Extreme care should be taken to avoid contact with voltages at various points on the chassis when the line cord is connected.

IMPORTANT

Follow the exact calibration sequence since many adjustments are interelated.

b. Fuse Checks.

1. Check the line fuse (F301) on the rear panel. For nominal 117V line operation, use a 2.5A type 3AG Slo-Blo fuse. For 234V line operation, use a 1.25A type 3AG Slo-Blo fuse.

2. Check the internally installed protection fuse (F101). This fuse is located on circuit board PC-330 near the front panel. Remove the top cover to gain access to the circuit board.

NOTE

If the Line Fuse (F301) is blown or missing, the Model 227 will be inoperable. If the protection fuse (F101) is blown or missing, the Model 227 will be operable, except the rear panel Current Monitor and Voltage Programming terminals.

c. Line Voltage Setting. Set the Line Switches (S302 and S303) in accord with paragraph 2-3 in Section 2.

d. Preliminary Check.

1. Set OUTPUT SELECTOR switch to "SHORT".
2. Set Range Switch to 1000μA.
3. Set Decade Switches to 10-0-0.
4. Set Polarity Switch to "+".
5. Set METER Switches to "X10" and "A".
6. Set VOLTAGE COMPLIANCE to "0" (minimum).
7. Put External short on Model 227.
8. Set Power Switch to "ON".
9. Set OUTPUT SELECTOR to "ON.
10. Set VOLTAGE COMPLIANCE to 10V.

TABLE 6-2.
Recommended Test Equipment for Calibration.

Item	Description	Minimum Specifications	Mfr.	Model
E	Digital Voltmeter	1.00000V ±(0.015% of rng + 0.015% of rdg)	Keithley	190
F	Oscilloscope	5mV/div. sensitivity 1MHz bandwidth	Tektronix	---
G	Digital Voltmeter	3-1/2 digits, 0 ± 1000V, ±0.2% of rdg	Keithley	168

11. Observe Meter (M101) reading. Current reading should be (+) full range.

12. Set Polarity Switch to "-".

13. Observe meter (M101) reading. Reading should be (-) full range.

14. Verify Meter readings for Range Settings of ±10, ±100, and ±1000mA.

15. If all ranges are indicated correctly, proceed to normal verification procedure.

e. Power Supply Adjustment.

1. Set controls as indicated in paragraph 5-3c (except no external short).

2. Remove the Model 227 top cover and bottom cover.

3. Locate potentiometer R306 on circuit board PC-331.

4. Connect DVM (Item G) between +325V test point and 0 HV test point.

5. Adjust potentiometer R306 for a voltage reading of +325V ± 1V.

NOTE

If thermal breaker TK301 is open or faulty, no voltage reading can be made.

f. Bias Adjustment.

1. Set controls as indicated in paragraph 5-3c, steps 1 through 8 (except no output short).

2. Connect a 30 kilohm resistive load (1%, 10 watt) to Output terminals.

3. Connect Oscilloscope (Item F) across the resistive load to monitor the compliance voltage. Oscilloscope must be ac coupled.

4. Set the front panel VOLTAGE COMPLIANCE control (R101) to maximum (fully clockwise).

5. Set Range Switch to "100mA".

6. Set Decade Dials to 1-0-0.

7. Set OUTPUT SELECTOR Switch to "ON".

8. Adjust the VOLTAGE COMPLIANCE control (R101), until compliance Limit indicator (DS104) just lights (monitor oscillation on scope).

9. Set potentiometer R220 fully clockwise before performing step 10.

10. Adjust potentiometer R220 to reduce oscillations to zero.

11. Do Step 8 to insure no oscillation occurs.

12. Monitor voltage across R225 (0.39Ω) should be 0.012V, no more than 0.015V.

g. 50V and 300V Compliance Adjust.

NOTE

To keep the correct air flow across the heat sinks, place the top cover (loose) on the Model 227, offset just enough to gain access to adjustments. Otherwise internal power dissipation could cause excessive temperature variation which could void the calibration.

1. Remove top and bottom covers.

2. Connect DVM (G) to output.

3. Set Decade Dials to 10-10-10.

4. Set Polarity Switch to "+".

5. Set VOLTAGE COMPLIANCE to maximum.

6. Set OUTPUT SELECTOR to "ON".

7. Set Range to 1000mA.

8. Adjust potentiometer R102 for an output of +55V ± 0.3V.

9. Set Polarity to "-".

10. Check output voltage.

11. Readjust potentiometer R102 on that polarity with the lowest absolute value of voltage for ±(55V ±0.3V).

12. Set Range to 100mA.

13. Set Polarity to "+".

14. Adjust potentiometer R104 for an output of +305V ± 1V.

15. Set Polarity to "-".

16. Check output voltage.

17. Readjust potentiometer R104 on that polarity with the lowest absolute value of voltage for ±(305V ±1V).

18. Repeat steps 11 through 17 until all readings are within tolerance.

NOTE

Polarity with highest voltage does not have to be within the 55 ± 0.3V or 305 ± 1V. But should be no greater than 58 or 320.

h. Current Zero Adjust.

1. Connect a 100Ω resistive load to output.

2. Set Decade Dials to 0-0-0*. (Set R124 fully CCW.)

3. Set Range to 10mA.

4. Connect DVM (E) across output load.

5. Set OUTPUT SELECTOR to "ON".

6. Set Polarity to "+" and take note of voltage reading.

7. Set Polarity to "-" and take note of voltage reading.

8. Adjust potentiometer R118 so that the absolute value of the voltages in steps 6 and 7 are within 10μV of each other.

NOTE

Output polarity should change opposite to Polarity Switch settings.

9. Set Fine Control R124 for 0-0-5 (set 5 carefully).

10. DVM (Item E) should read 0.005V ± 0.0001V if not, go to step 11. If within tolerance, go to Section 6-4i below.

NOTE

Set OUTPUT SELECTOR to "SHORT" between measurements.

11. Loosen knob on Fine Control and align knob to "5" position (without disturbing potentiometer setting).

NOTE

Do not disturb R124 setting of "5".

i. Full Range Current Calibration.

1. Set Range to 10mA.

2. Set Decade Dials to 10-0-5.

3. Connect a 100 ohm (0.01%, 10ppm/°C, 1/8W) resistive load to the output.

4. Connect DVM (E) across output terminals.

5. Set VOLTAGE COMPLIANCE to 10.

6. Set OUTPUT SELECTOR to "ON".

7. Set Polarity to "+".

8. Monitor output voltage of DVM.

9. Adjust potentiometer R129 for an output of 1.0050V ± 0.00017V.

j. Volts Monitor Zero Adjust.

1. Set Decade Dials to 0-0-0.

2. Set Range to 10mA.

3. Connect short across output.

4. Connect DVM (E) across VOLTS MONITOR (HI-LO), on rear panel.

HI = Blue (J105)
LO = Black (J106)

5. Set OUTPUT SELECTOR to "ON".

6. Adjust potentiometer R135 for an output of 0.0000V ± 0.0001V.

k. Meter Calibration.

1. Set OUTPUT SELECTOR to "SHORT".

2. Set Decade Dials to 0-0-0.

3. Adjust mechanical zero as necessary.

4. Set Decade Dials to 1-0-0.

5. Set Range to 10mA.

6. Set METER Switch to X1 and A.

7. Set Polarity to "+".

8. Set OUTPUT SELECTOR to "ON".

9. Adjust potentiometer R133 for full range (10) reading.

10. Set Polarity to "-".

11. Readjust potentiometer R133 so that error between + and - polarity is equal.

12. Set Meter Switch to X10 and A.

13. Set Decade Dials to 10-0-0.

14. Check both polarities by alternately switching Polarity Switch to "+" and "-".

15. Check to see the meter error is no greater than ≈5%.

6-5. MODEL 2271 ADJUSTMENT/CALIBRATION. (Model 2271 Installed in Model 227).

a. Power Supply Connections.

1. Connect external +5V Supply at J401 pin 4 (+5V) and pin 12 (common). External supply should be rated at +5V to +6V at 200 milliamperes.

NOTE

Calibration of the Model 2271 must be done with Model 227 Front Panel Polarity Switch in "+" position to insure meeting specification.

b. Current Source Adjust.

1. Connect test set-up as shown in Figure 29.

2. Set Range to Remote Programming.

3. Connect J401 pin 6 to pin 12 (common) to enable 10mA range.

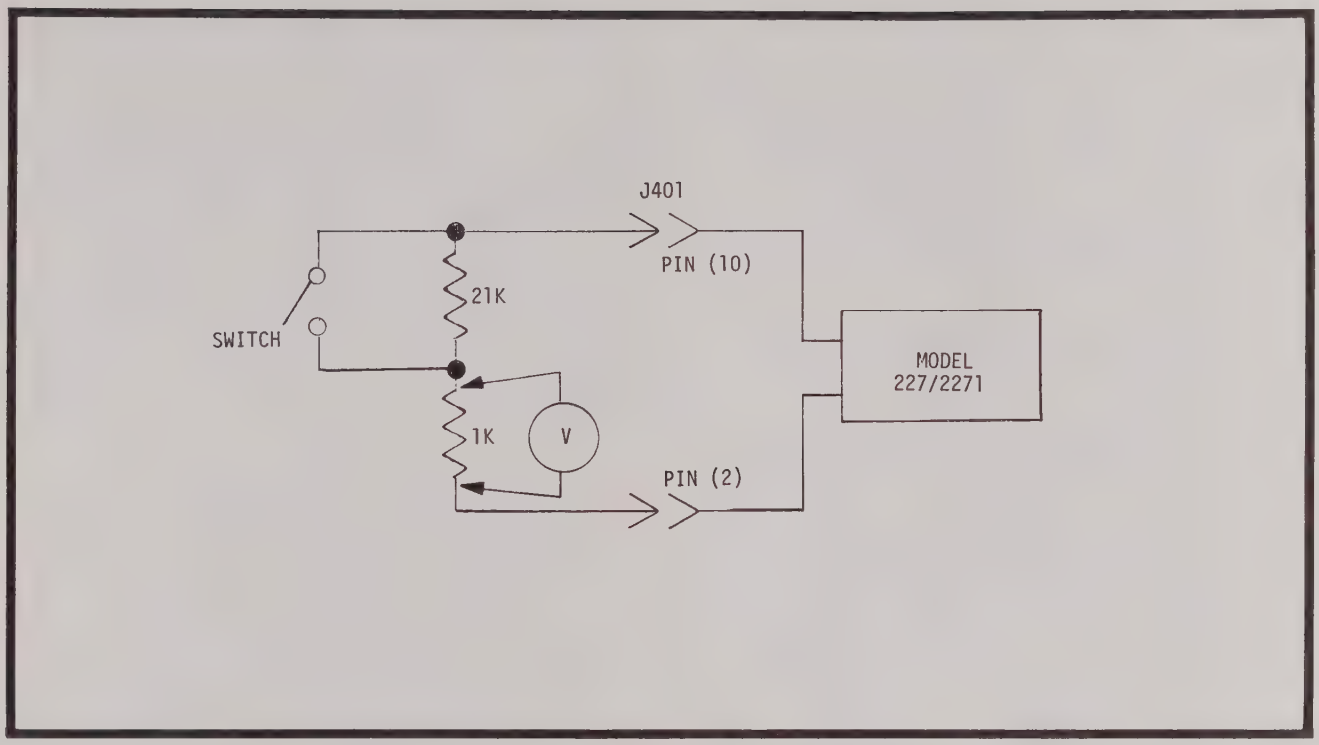


FIGURE 29. Test Set-up for Model 227/2271 Calibration.

4. Monitor voltage across 1kΩ resistor using DVM (A). Voltage should be approximately 100mV.

5. Adjust potentiometer R438 as necessary so that voltage across resistor is the same with switch closed or open (readings to be within ±10μV).

c. Resistance Program Zero Adjust.

1. Set 227 Polarity Switch to "+".

2. Connect a 11kΩ resistor (0.02%, 1/4W) between J401 pins 2 and 10.

3. Connect a 100Ω resistor (0.01%, 1/2W) at Model 227 output terminals.

4. Connect DVM (A) across resistor (most sensitive range).

5. Turn OUTPUT SELECTOR Switch to "ON".

6. Adjust potentiometer R412 so that DVM reading is 0.00000 ± 200μV.

d. Current Cal. (- Full Range).

1. Connect a 21kΩ resistor (0.02%, 1/4W) between J401 pins 2 and 10.

2. Connect a 100Ω resistor at Model 227 output terminals.

3. Connect DVM (A) across resistor. (1V Range.)

4. Adjust potentiometer R407 for -1.00000 ± 150 μV reading at output.

e. Iterative Current Cal/Zero Adjust. Repeat steps c and d until both conditions are satisfied.

NOTE

Set the Zero Adjust (R412) in opposite polarity an equal amount to error so that interation will converge with fewest number of operations. If potentiometer R407 does not allow sufficient adjustment range, jumper across R406 may have to be cut or reinstalled.

f. Current Verification (+ Full Range).

1. Connect a 1kΩ resistor (0.02%, 1/4W) between J401 pins 2 and 10.

2. Connect a 100 resistor at Model 227 output terminals.

3. Connect DVM (A) across resistor (1V range).

4. Check to see that output on DVM (A) is +1.00000 ± 550μV reading at output.

5. Set SELECTOR Switch to "SHORT".

g. Ext. Compliance Limit (Maximum).

1. Connect J401 pin 8 to pin 12 (common).

2. Remove connections between J401 pins 2 and 10 (leave open).

3. Connect DVM (A) at Model 227 output.

4. Connect J401 pin 15 to pin 12 (common).

CAUTION

Up to 300 volts is present at various rear panel terminals as well as internal circuit points.

5. Connect J401 pin 1 to pin 9.

6. Connect a 1kΩ resistor (0.02%) between J401 pins 2 and 10.

7. Set OUTPUT SELECTOR Switch to "ON".

8. Record voltage reading at output.

9. Connect a 21kΩ resistor (0.02%) between J401 pins 2 and 10. (Remove 1kΩ resistor).

10. Compare reading of step 9 to that of step 10.

11. Select resistor value (1kΩ or 21kΩ) which gives the lowest (absolute value) reading.

12. With this resistor installed, adjust potentiometer R405 for a reading of 305V ± 1V.

13. Set OUTPUT SELECTOR Switch to "SHORT".

14. Remove connection at J401, pin 15.

15. Set OUTPUT SELECTOR Switch to "ON".

16. Output voltage should read 55V ± 2V.

17. Set OUTPUT SELECTOR Switch to "SHORT".

18. Remove connection between J401 pins 1 and 9.

h. Ext. Compliance Limit (Minimum).

1. Connect a 1kΩ resistor between J401 pins 2 and 10.

2. Connect J401 pin 15 to pin 12.

3. Connect DVM (A) across output.

NOTE

Make certain no connection is made between J401 pins 1 and 9 (open).

4. Set OUTPUT SELECTOR Switch to "ON".

5. Voltage at output should be less than 9V volts (positive).

6. Connect 21kΩ resistor between J401 pins 2 and 10.

7. Voltage at output should be less than 9V volts (negative).

8. Repeat steps 2 through 7 with J401 pin 15 not connected to pin 12. Voltage reading should be less than ±3.5V.

6-6. MODEL 2271 CHECKOUT (Not Installed in Model 227).

a. Power Supply Check.

1. Connect external ±12 volt supply (needed only for check-out purposes) to printed circuit board PC-342. Connector J405 pin F should be +12V with respect to pin B. Connector J405 pin E should be -12V with respect to pin B.

2. Connect external +5V supply to connector J401 pin 4, (+5V) and pin 12 (common). External supply should be rated at +5V to +6V at 200 milliamperes.

b. Relay Check. (An ohmmeter is required for this check to verify open circuit and short circuit conditions.)

NOTE

Connect J404 pin B to 12V common (J405, pin B) to energize relay K408. This action connects the +5V supply to Model 2271 circuitry.

1. Remote Compliance Limit (Relay K407).

a). Momentarily connect J401 pin 8 to pin 12 (+5V common) to energize K407.

b). Check condition of relay contacts at J405 G and D using an Ohmmeter.

c). Contacts should open (infinite resistance) when closure to common is made.

2. 300V Compliance Range (Relay K406).

a). Momentarily connect J401 pin 15 to pin 12 (common) to energize K406.

b). Check condition of relay contacts at J405 K and H using an Ohmmeter (H).

c). Contacts should close (zero resistance) when closure to common is made.

d). Check condition of relay contacts at K406A pins 5 and 6 or across R419.

e). Resistance should change from 0Ω to approximmately 20kΩ when closure to common is made.

f). Leave J401 pin 15 to pin 12 connected for next test.

3. 1000mA Range (Relays K404, K405, and K406).

a). Momentarily connect J401 pin 7 and pin 12.

b). Check condition of relay contacts at J405 K and H using an ohmmeter.

c). Contacts should open (infinite resistance) when closure to common is made.

d). Check condition of relay contacts at J404 pin K and pin C using an Ohmmeter (B).

e). Contacts should close (zero resistance) when closure to common is made.

f). Remove connections between pins 7, 12, and 15 before proceeding to next step.

4. 100mA Range (Relay K403).

a). Momentarily connect J401 pin 14 to pin 12 (common) to energize relay K403.

b). Check condition of relay contacts at J404 pin K and F.

c). Contacts should close (zero resistance) when closure to common is made.

5. 10mA Range (Relay K402).

a). Momentarily connect J401 pin 6 to pin 12 (common) to energize relay K402.

b). Check condition of relay contacts at J404 pin K and E.

c). Contacts should close (zero resistance) when closure to common is made.

6. 1000μA Range (Relay K401).

a). Momentarily connect J401 pin 13 to pin 12 (common) to energize relay K401.

b). Check condition of relay contacts at J404 pin K and A.

c). Contacts should close (zero resistance) when closure to common is made.

c. Compliance Monitor Check.

1. Connect a 312Ω resistor (5%, 1/2W) between J401 pin 5 and pin 4 (+5V supply).

NOTE

Current through the 312Ω resistor should be 16mA. Set the +5 volt supply to achieve the current.

2. Voltage between J401 pin 5 and pin 12 should be less than +0.4V. (Leave resistor connected for next step.)

3. Connect a 360Ω resistor (5%, 1/2W) between J406 pin A and J405 pin F (+12V supply).

4. Connect a jumper wire between J406, pin B to J405, pin B (12V common).

5. Voltage at J401 pin 5 should be greater than +2.4V.

6. Disconnect resistors and jumper.

NOTE

Should it be necessary to remove the Model 2271 Option from the Model 227 chassis, connector J206A, furnished with each 227/2271 (shown on schematic 26226E) must be installed at P206. Connector J206A is a ten-pin Berg Connector with jumper wires between pins A and C; D and G.

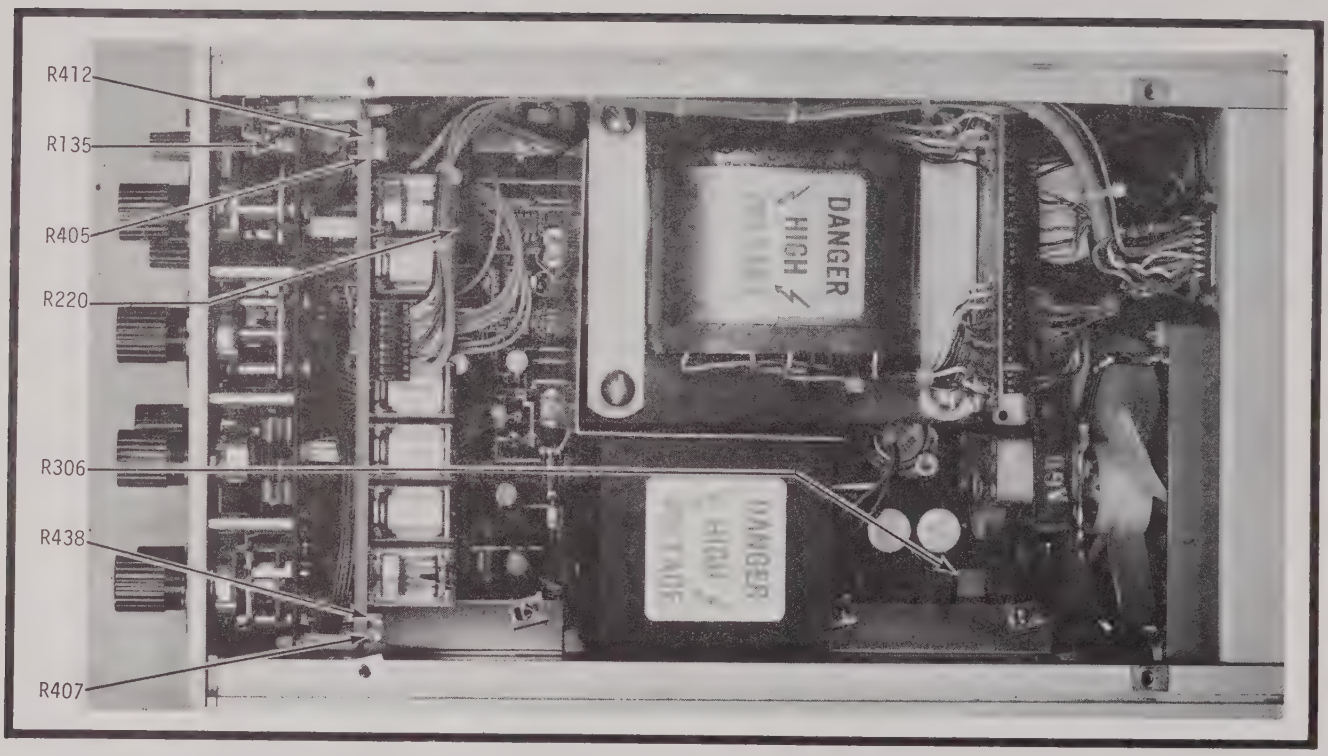


FIGURE 30. Location of Adjustments with Top Cover Removed.

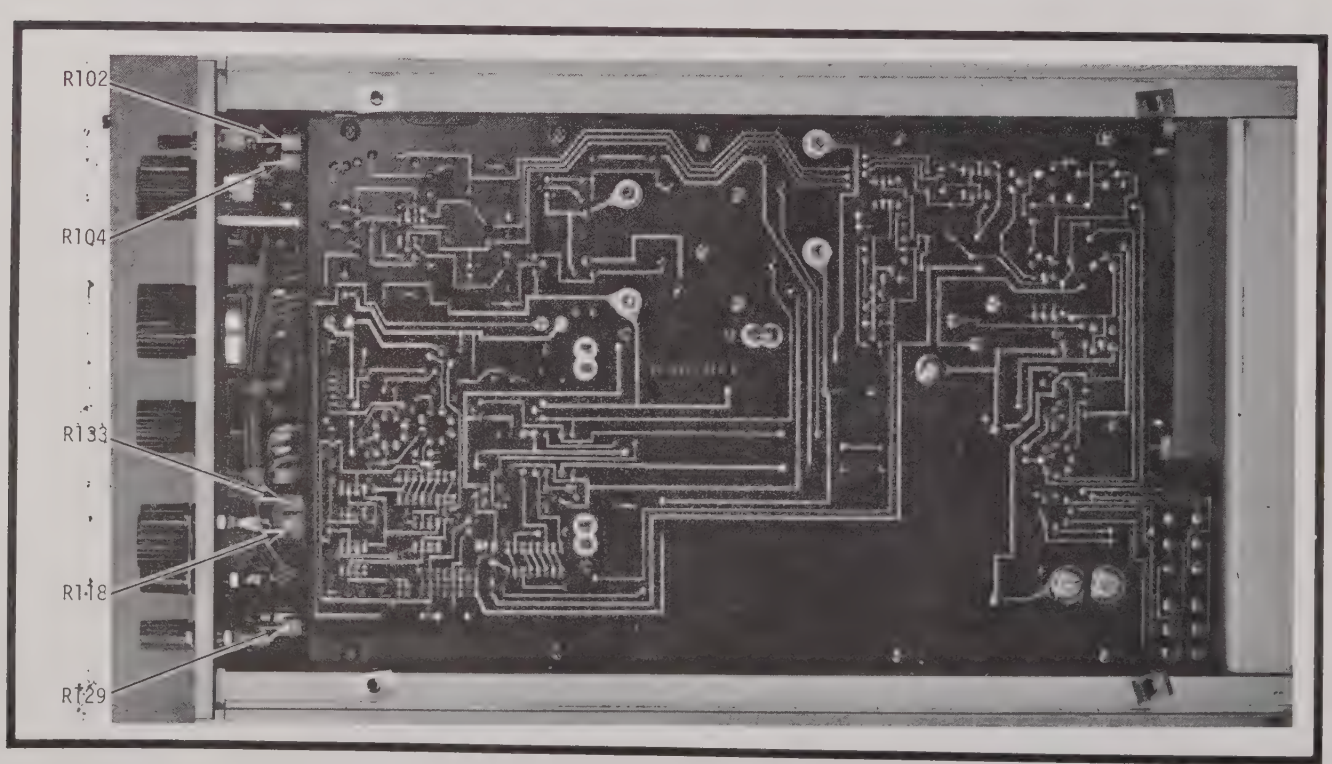


FIGURE 31. Location of Adjustments with Bottom Cover Removed.

SECTION 7. REPLACEABLE PARTS

7-1. GENERAL. This section contains information for ordering replacement parts. The parts list is arranged in alphameric order of their Circuit Designations.

7-2. ORDERING INFORMATION. To place an order or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover of the manual for addresses. When ordering, include the following information:

a. Instrument Model Number

b. Instrument Serial Number

c. Part Description

d. Circuit Designation (if applicable)

e. Keithley Stock Part Number.

7-3. SCHEMATIC DIAGRAMS.

a. Power Supply (26227D). This schematic describes the line-operated power supply, including fuses, fan, and thermal circuit-breaker. Circuit designation series is "300".

b. Current Source (26226E). This schematic describes the range switching, regulating amplifiers, reference amplifier, and other controls. Circuit designation series is "100" for Switch Board, PC-330 and "200" for Mother Board, PC-331.

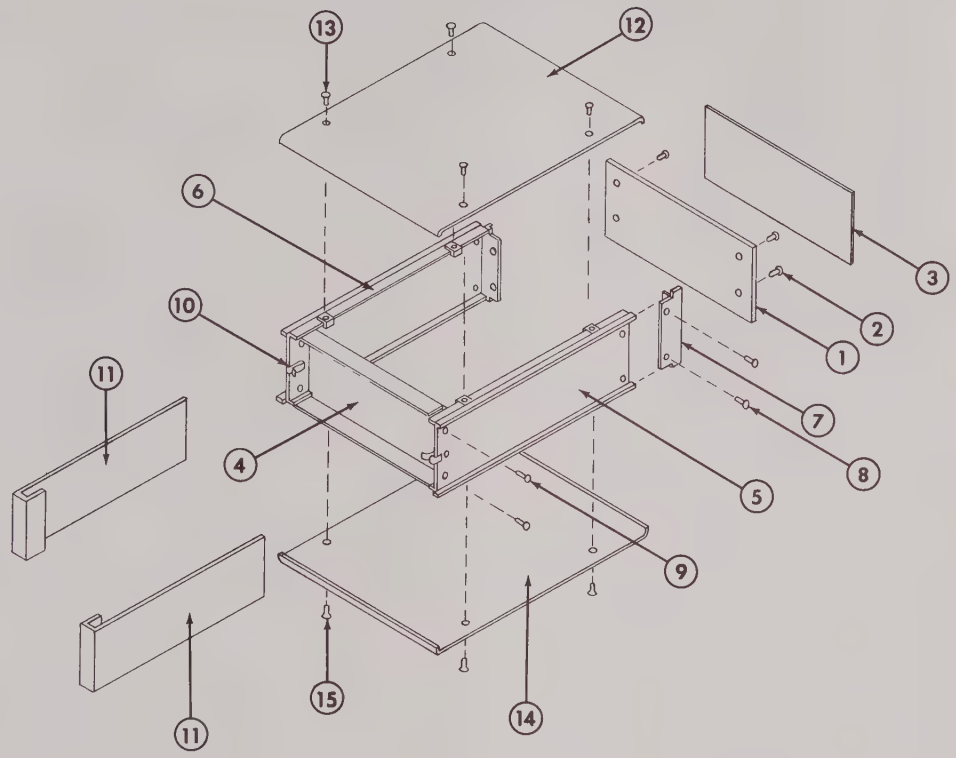
c. Model 2271 Programming Option (26608E). This schematic describes the controls for range, current, and compliance. Circuit designation series is "400".

TABLE 7-1.
PC Board Designation Series

Series	Description	Designation	Page No.
100	Switch Board	PC-330	52
200	Amplifier } Mother Board	PC-331	54
300	Power Supply	PC-331	54
400	Remote Programming Circuit (Model 2271)	PC-342	57

TABLE 7-2.
Mechanical Parts List

Item No.	Description	Qty. Per Assembly	Keithley Part No.	Figure Number
-	Chassis Assembly	-	-	32
-	Front Panel Assembly	-	-	
1	Front Panel	1	25565C	
2	Screw, Slotted, 6-32 x 3/8	4	-	
3	Front Panel Overlay	1	25566C	
4	Rear Panel	1	25568B	
5	Side Extrusion Left	1	26000C	
6	Side Extrusion Right	1	25899C	
7	Corner Bracket	2	25555B	
8	Screw, Socket, 6-32 x 1/4	4	-	
9	Screw, Phillips, 6-32 x 1/4	4	-	
10	Clip for Side Dress	2	FA-101	
11	Side Dress Panel	2	25560B	
-	Top Cover Assembly	-	-	32
12	Top Cover	1	25787B	
13	Screw, Socket, 6-32 x 5/16	4	-	
-	Bottom Cover Assembly	-	25564B	32
14	Bottom Cover	1	25563B	
15	Screw, Socket, 6-32 x 5/16	4	-	
-	Feet Assembly	-	-	
16	Feet	4	24322B	
17	Ball	4	FE-6	
18	Tilt Bail	1	17147B	
19	Screw, Phillips, 6-32	4	-	
20	Kep Nut, 6-32	4	-	



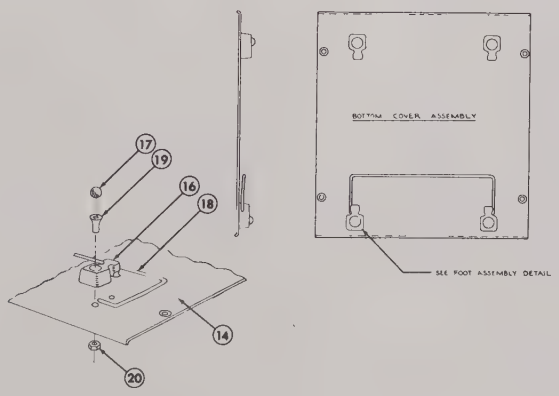


FIGURE 32. Chassis Assembly.

TABLE 7-3.
Cross-Reference of Manufacturers

ABREV.	Name and Address
ALCO	Alco Electronics Products, Inc. Lawrence, MA. 01843
A-B	Allen-Bradley Corp. Milwaukee, WI. 53204
AMMON	Ammon Instruments, Inc. Manchester, NH. 03105
AMPRX	Amperex Elkgrove Village, IL. 60007
BECK	Beckman Instruments, Inc. Fullerton, CA. 92634
BELD	Belden Manufacturing Co. Chicago, IL. 60644
BERG	Berg Electronics, Inc. New Cumberland, PA. 17070
CENLB	Centralab Division Milwaukee, WI. 53201
CLARO	Clarostat Manufacturing Co., Inc. Dover, NH. 03820
COMPI	Components, Inc. Biddeford, ME. 04005
C-W	Continental-Wirt Electronics Corp. Philadelphia, PA.
CTS	CTS Corporation Elkart, IN. 46514
DALE	Dale Electronics, Inc. Columbus, NB. 68601
DELCO	Delco Electronics Div. Kokomo, IN. 46901
DICK	Dickson Electronics Corp. Scottsdale, AZ. 85022
EDI	Electronic Devices Inc. Yonkers, NY. 10710
ERIE	Erie Technological Products, Inc. Erie, PA. 16512
FAIR	Fairchild Instruments Corp. Mountain View, CA. 94040
FUSE	Fusetron (Bussman Mfg. Div.) St. Louis, MO. 63107
G-E	General Electric Company Syracuse, NY. 13201
GRIFF	Griffith Plastic
HOW	Howard Industries Racine, WI. 53404
IEE	Industrial Electric Engineers, Inc. Van Nuys, CA. 91405
IEC	International Electronics Corp. Long Island, NY 11746
IRC	IRC Division Burlington, IA. 52601
LITFU	Littlefuse, Inc. Des Plaines, IL. 60016
MAL	Mallory Capacitor Indianapolis, IN. 46206
MOLEX	Molex Duners Grove, IL. 60515
MOT	Motorola Semiconductor Products, Inc. Phoenix, AZ. 85008
NAT	National Semiconductor Corp. Danbury, CN. 06810
POTT	Potter Company Wesson, MI. 39191
RCA	RCA Corporation Somerville, NJ. 08876
SOL	Solitron Devices, Inc. Tappan, NY. 10983
SPRAG	Sprague Electric Company Visalia, CA. 93278
SUPER	Superior Electric Co. Bristol, CN. 06012
S-C	Switchcraft, Inc. Chicago, IL. 60630
TEMPL	Temple Tecate, CA. 92080
TEPRO	Tepro Clearwater, FL. 33517
TEXAS	Texas Instruments Dallas, TX. 75231
THERM	Therm-O-Disc., Inc. Mansfield, OH. 44907

REPLACEABLE PARTS LIST
(Schematics 26226E,and 26227D)

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C101	10µF, 20V, ETT.	COMPI	TD2-20-106-20	C179-10M	7
C102	10µF, 20V, ETT.	COMPI	TD2-20-106-20	C179-10M	..
C103	0.01µF, 500V, CerD.	ERIE	871-Z5U0-103M	C22-0.01M	4
C104	4.7µF, 20V, ETT	COMPI	TD1-20-475-20	C179-4.7M	5
C105	10µF, 20V, ETT.	COMPI	TD2-20-106-20	C179-10M	..
C106	0.1µF, 250V, MtF.	AMPRX	C280AE/P100K	C178-0.1M	1
C107	0.01µF, 500V, CerD.	ERIE	871-Z5U0-103M	C22-0.01M	..
C108	0.01µF, 500V, CerD.	ERIE	871-Z5U0-103M	C22-0.01M	..
C109	100pF, 1000V, CerD.	CENLB	DD-101	C64-100P	1
C110	0.02µF, 500V, CerD.	ERIE	811-Z5U0-203M	C22-0.02M	1
C111	220pF, 1000V, CerD.	CENLB	DD-221	C64-220P	1
C112	0.02 µF, 500V, CerD.	ERIE	871-Z5U0-203M	C22-0.02M	..
C201	22pF, 1000V, CerD	CENLB	DD-220	C64-22P	2
C202	22pF, 1000V, CerD	CENLB	DD-220	C64-22P	..
C203	0.33µF, 50V, CerF	ERIE	8131050651334M	C237-0.33M	1
C204	0.02µF, 500V, CerD.	ERIE	811-Z5U0-203M	C22-0.02M	2
C205	0.02µF, 500V, CerD.	ERIE	811-Z5U0-203M	C22-0.02M	..
C208	0.0047µF, 1000V, CerD	SPRAG	10SS-D47	C64-0.0047M	1
C209	Not Used.	...	...	...	..
C210	4.7µF, 20V, ETT	COMPI	TD1-20-475-20	C179-4.7M	..
C211	4.7µF, 20V, ETT	COMPI	TD1-20-475-20	C179-4.7M	..
C212	470pF, 1000V, CerD.	CENLB	DD-471	C64-470P	4
C213	0.047µF, 600V, MPF.	IEC	CM470-6A	C220-0.047M	1
C214	4.7µF, 20V, ETT	COMPI	TD1-20-475-20	C179-4.7M	..
C215	4.7µF, 20V, ETT	COMPI	TD1-20-475-20	C179-4.7M	..
C216	0.001µF, 1000V, CerD.	ERIE	808000Z5R0-102K	C64-0.001M	1
C217	470pF, 1000V, CerD.	CENLB	DD-471	C64-470P	3
C218	470pF, 1000V, CerD.	CENLB	DD-471	C64-470P	..
C219	470pF, 1000V, CerD.	CENLB	DD-471	C64-470P	..
C220	0.1µF, 400V, My	POTT	SM1A-0.1µF	C73-0.1M	3
C221	0.1µF, 400V, My	POTT	SM1A-0.1µF	C73-0.1M	..
C222	100pF, 1000V, CerD.	CENLB	DD-101	C64-100P	..
C301	20µF, 450V, ETB	MAL	TC75-20µF	C8-20	1
C302	940µF, 100V, EAL.	G-E	86F183M-940µF	C239-940M	1
C303	680pF, 1000V, CerD.	CENLB	DD-681	C64-680P	1
C304	0.1µF, 400V, My	POTT	SM1A-0.1µF	C73-0.1M	..
C305	470µF, 50V, EAL	TEMPL	411-470µF	C246-470M	2
C306	10µF, 20V, ETT.	COMPI	TD2-20-106-20	C179-10M	..
C307	10µF, 20V, ETT.	COMPI	TD2-20-106-20	C179-10M	..
C308	470µF, 50V, EAL	TEMPL	411-470µF	C246-470M	..
C309	10µF, 20V, ETT.	COMPI	TD2-20-106-20	C179-10M	..
C310	10µF, 20V, ETT.	COMPI	TD2-20-106-20	C179-10M	..
C312	22µF, 20V, ETT.	COMPI	TD1-20-226-20	C179-22M	1
C331	0.047µF, 250V, MtF.	AMPRX	C280AE/P47K	C178-0.047M	1

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
CR101	Zener, 2.6V	TEXAS	1N702A	DZ-33	1
CR102	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	13
CR103	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR104	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR105	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR106	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR107	Zener, 5.8V	DICK	1N706	DZ-1	3
CR108	Zener, 5.8V	DICK	1N706	DZ-1	..
CR109	Zener, 5.8V	DICK	1N706	DZ-1	..
CR110	Zener, 6.3V, 250 mW	M-S	1N827A Selected	28619A	1
CR111	Zener, 20V, 2W.	DICK	ZEZ20D5	DZ-52	2
CR112	Zener, 20V, 2W.	DICK	ZEZ20D5	DZ-52	..
CR201	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR202	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR203	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR204	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR205	Rectifier, 3A, 50V (1N4139)	SOL	3A50	RF-34	1
CR209	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR210	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR211	Diode Network	FAIR	FSA2619M	DN-2	2
CR212	Diode Network	FAIR	FSA2619M	DN-2	..
CR301	Four-diode, full-wave bridge, 2A, 100V.	EDI	PD-10	RF-36	1
CR302	Four-diode, full-wave bridge, 1.5A, 400V.	EDI	PF-40	RF-46	1
CR303	Zener, 24V, 0.25W	DICK	1N723	DZ-17	1
CR304	Rectifier, 3A, 400V	EDI	HAB040	RF-47	1
CR305	Rectifier, 1A, 800V	MOT	4006	RF-38	3
CR306	Rectifier, 1A, 800V	MOT	4006	RF-38	..
CR307	Rectifier, 1A, 800V	MOT	4006	RF-38	..

DISPLAYS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DS101	Pilot Lamp, 6V.	IEE	7345-AS25	PL-57	4
DS102	Pilot Lamp, 6V.	IEE	7345-AS25	PL-57	..
DS103	Pilot Lamp, 6V.	IEE	7345-AS25	PL-57	..
DS104	Pilot Lamp, 6V.	IEE	7345-AS25	PL-57	..

FUSES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
F101	Fuse, 0.125A, 8AG	LITFU	361.125	FU-5	1
F301	Fuse, 1.25A, 250V, 3AG, SLO-BLO (234V).	FUSE	MDX-1.25	FU-28	1
F301	Fuse, 2.5A, 250V, 3AG, SLO-BLO (117V)	FUSE	MDA-2.5	FU-45	1

CONNECTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J101	Banana Jack, Yellow	POM	2854-4	BJ-9-4	1
J102	Banana Jack, White.	POM	2854-9	BJ-9-9	2
J103	Banana Jack, Blue	POM	2854-6	BJ-9-6	2
J104	Banana Jack, White.	POM	2854-9	BJ-9-9	..
J105	Banana Jack, Blue	POM	2854-6	BJ-9-6	..

CONNECTORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J106	Banana Jack, Black.	POM	2854-0	BJ-9-0	2
J107	Banana Jack, Red.	POM	2854-2	BJ-9-2	1
J108	Banana Jack, Black.	POM	2854-0	BJ-9-0	..
J109	Banana Jack, Red (Modified BJ-9-2).	POM	2854-2	27484A-2	1
J110	Banana Jack, Black (Modified BJ-9-0).	POM	2854-0	27484A-0	1
J111	Banana Jack, Green (Modified BJ-9-5).	POM	2854-5	27484A-5	1
J201	Housing, 10-pins.	BERG	20052	CS-237	5
J202	See Model 2271.	...	...	...	..
J203	Housing, 2-pins, MINI-PV.	BERG	65039-035	CS-266	1
J204	Not Used.	...	...	...	..
J205	Housing, 10 pins.	BERG	20052	CS-237	..
J206	Housing, 10-pins.	BERG	20052	CS-237	..
J207	See Model 2271.	...	...	...	..
J301	Line Receptacle	S-C	EAC301	CS-254	1
J302	Housing, 10-pins.	BERG	20052	CS-237	..
J303	Housing, 2-pins	MOLEX	2139-2	CS-275	1
J304	Housing, 10-pins.	BERG	20052	CS-237	..
J305	Housing, 5-pins, MINI-PV.	BERG	65039-034	CS-270	1
P101-111	Not Used.	...	...	...	..
P303	Plug, 2-pins.	MOLEX	2402-2A	CS-277	1

TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q101	PNP, Case TO-106.	FAIR	2N5139	TG-66	2
Q102	PNP, Case TO-106.	FAIR	2N5139	TG-66	..
Q201	NPN, Case TO-5.	RCA	2N3439	TG-93	3
Q202	NPN, Power Type, 3.5A, 100W, TO-3 Case.	DELCO	DTS-409	TG-113	5
Q203	NPN, Case TO-106.	FAIR	2N3565	TG-39	4
Q204	NPN, Power Type, Case TO-220.	MOT	2N5190	TG-108	2
Q205	PNP, Power Type, 40W, 4A, Case TO-220	MOT	2N5193	TG-107	2
Q206	PNP, Case TO-106.	FAIR	2N4355	TG-90	1
Q207	NPN, Power Type, 3.5A, 100W, TO-3 Case.	DELCO	DTS-409	TG-113	..
Q208	PNP, Power Type, 1A, 10W, Case TO-5	RCA	2N5416	TG-105	2
Q209	PNP, Case TO-5.	RCA	2N3439	TG-93	..
Q210	PNP, Power Type, 1A, 10W, Case TO-5	RCA	2N5416	TG-105	..
Q211	NPN, Power Type, 3.5A, 100W, TO-3 Case.	DELCO	DTS-409	TG-113	..
Q212	NPN, Power Type, 3.5A, 100W, TO-3 Case.	DELCO	DTS-409	TG-113	..
Q301	NPN, Case TO-5.	RCA	2N3439	TG-93	..
Q302	NPN, Power Type, 3.5A, 100W, TO-3 Case.	DELCO	DTS-409	TG-113	..
Q303	NPN, Case TO-106.	FAIR	2N3565	TG-39	..
Q304	NPN, Case TO-106.	FAIR	2N3565	TG-39	..
Q305	NPN, Case TO-106.	FAIR	2N3565	TG-39	..
Q306	PNP, Power Type, 4A, 40W, Case TO-220	MOT	2N5193	TG-107	..
Q307	NPN, Power Type, 4A, 40W, Case TO-220	MOT	2N5190	TG-108	..

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R101	5kΩ, Var.	CLARO	47-5kΩ	RP105-5K	1
R102	20kΩ, Cermet.	BECK	89P-20kΩ	RP89-20K	2
R103	3.3kΩ, 10%, 0.25W, Comp	A-B	CB-332-10%	R76-3.3K	1
R104	1kΩ, Cermet	BECK	89P-1kΩ	RP89-1K	2
R105	499Ω, 1%, 0.12W, MtF.	IRC	CEA-TO-499	R-88-499	1
R106	5.6kΩ, 10%, 0.25W, Comp	A-B	CB-562-10%	R76-5.6K	1
R107	137Ω, 1%, 0.5W, MtF	IRC	CEC-TO-137Ω	R94-137	1
R108	100Ω, 10%, 0.25W, Comp.	A-B	CB-101-10%	R76-100	1
R109	1.5kΩ, 10%, 0.25W, Comp	A-B	CB-152-10%	R76-1.5K	1
R110	1kΩ, 10%, 0.25W, Comp	A-B	CB-102-10%	R76-1K	3
R111	3.9kΩ, 10%, 0.25W, Comp	A-B	CB-392-10%	R76-3.9K	1
R112	100Ω, 10%, 0.5W, Comp	A-B	ED-101-10%	R1-100	2
R113	100Ω, 10%, 0.5W, Comp	A-B	ED-101-10%	R1-100	..
R114	1200Ω, 0.1%, 0.12W, MtF	DALE	MFF-1/8-T21200Ω	R176-1200	1
R115	800Ω, 0.1%, 0.12W, MtF.	DALE	MFF-1/8-T2-800Ω	R176-800	1
R116	400Ω, 0.1%, 0.12W, MtF.	DALE	MFF-1/8-T2-400Ω	R176-400	1
R117	1kΩ, 10%, 0.25W, Comp	A-B	CB-102-10%	R76-1K	..
R118	10kΩ, Cermet.	BECK	89P-10kΩ	RP89-10K	..
R119	1kΩ, 0.1%, 0.12W, MtF	DALE	MFF-1/8-1kΩ	R168-1K	2
R120	820Ω, 10%, 0.25W, Comp.	A-B	CB-821-10%	R76-820	1
R121	4.02kΩ, 1%, 0.12W, MtF.	DALE	MFF-1/8-T94.02kΩ	R177-4.02K	2
R122	6.5kΩ, 0.1%, 0.12W, MtF	DALE	MFF-1/8-T2-6.5K	R176-6.5K	1
R123	2.5kΩ, 0.1%, 0.12W, MtF	DALE	MFF-1/8-T22.5kΩ	R176-2.5K	1
R124	50Ω, Cermet	CTS	550-50Ω	RP106-50	1
R125	120Ω, 0.5%, 0.12W, MtF.	DALE	MFF-1/8-120Ω	R234-120	1
R126	80Ω, 0.5%, 0.12W, MtF	DALE	MFF-1/8-80Ω	R234-80	1
R127	40Ω, 0.5%, 0.12W, MtF	DALE	MFF-1/8-40Ω	R234-40	1
R128	1.69kΩ, 1%, 0.12W, MtF.	DALE	MFF-1/8-1.69kΩ	R206-1.69K	1
R129	1kΩ, Cermet	BECK	89P-1kΩ	RP89-1K	1
R130	160Ω, 0.5%, 0.12W, MtF.	DALE	MFF-1/8-160Ω	R234-160	1
R131	681Ω, 1%, 0.5W, MtF	IRC	CEC-TO-681Ω	R94-681	2
R132	681Ω, 1%, 0.5W, MtF	IRC	CEC-TO-681Ω	R94-681	..
R133	500Ω, Cermet.	BECK	89P-500Ω	RP89-500	..
R134	10Ω, 10%, 0.5W, Comp.	A-B	ED-100-10%	R1-10	1
R135	100kΩ, Cermet	BECK	89P-100kΩ	RP89-100K	1
R136	1MΩ, 10%, 0.25W, Comp	A-B	CB-105-10%	R76-1M	1
R137	100kΩ, 10%, 0.25W, Comp	A-B	CB-104-10%	R76-100K	2
R138	100kΩ, 10%, 0.25W, Comp	A-B	CB-104-10%	R76-100K	..
R139	1kΩ, 10%, 0.25W, Comp	A-B	CB-102-10%	R76-1K	..
R140	Not Used				
R141	1.8kΩ, 10%, 0.25W, Comp	A-B	CB-182-10%	R76-1.8K	2
R142	8.2kΩ, 10%, 0.25W, Comp	A-B	CB-822-10%	R76-8.2K	2
R143	8.2kΩ, 10%, 0.25W, Comp	A-B	CB-822-10%	R76-8.2K	..
R144	1.8kΩ, 10%, 0.25W, Comp	A-B	CB-182-10%	R76-1.8K	..
R145	66.5kΩ, 1%, 0.5W, MtF	IRC	CEC-TO-66.5kΩ	R94-66.5K	2
R146	66.5kΩ, 1%, 0.5W, MtF	IRC	CEC-TO-66.5kΩ	R94-66.5K	..
R147	1.21MΩ, 1%, 0.5W, MtF	IRC	CEC-TO-1.21MΩ	R94-1.21M	1
R148	4.02kΩ, 1%, 0.12W, MtF.	DALE	MFF-1/8-T94.02kΩ	R177-4.02K	..
R149	3.57kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-3.57kΩ	R88-3.57K	1
R150	1600Ω, 0.1%, 0.12W, MtF	DALE	MFF-1/8-T21600Ω	R176-1600	1
R151	1kΩ, 0.1%, 0.12W, MtF	DALE	MFF-1/8-1kΩ	R-168-1k	..
R201	249kΩ, 1%, 0.5W, MtF.	IRC	CEC-TO-249kΩ	R94-249K	2
R202	249kΩ, 1%, 0.5W, MtF.	IRC	CEC-TO-249kΩ	R94-249K	..
R203	33kΩ, 10%, 0.25W, Comp.	A-B	CB-333-10%	R76-33K	2
R204	3.3kΩ, 10%, 0.25W, Comp	A-B	CB-332-10%	R76-3.3K	4
R205	3.32kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-3.32kΩ	R88-3.32K	4
R206	3.32kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-3.32kΩ	R88-3.32K	..
R207	7.68kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-7.68kΩ	R88-7.68K	2
R208	7.68kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-7.68kΩ	R88-7.68K	..
R209	3.3kΩ, 10%, 0.25W, Comp	A-B	CB-332-10%	R76-3.3K	..
R210	33kΩ, 10%, 0.25W, Comp.	A-B	CB-333-10%	R76-33K	..
R211	330Ω, 10%, 0.25W, Comp.	A-B	CB-331-10%	R76-330	2
R212	330Ω, 10%, 0.25W, Comp.	A-B	CB-331-10%	R76-330	..
R213	2.2kΩ, 10%, 0.25W, Comp	A-B	CB-222-10%	R76-2.2K	2
R214	2.2kΩ, 10%, 0.25W, Comp	A-B	CB-222-10%	R76-2.2K	..

RESISTORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R215	900Ω, 0.1%, 1W, MtF	TEP	TS-1	R249-900	1
R216	90Ω, 0.1%, 0.25W, MtF	RCL	7009	R95-90	1
R217	9Ω, 0.1%, 5W, WW.	TEPRO	TS5-9Ω	R232-9	1
R218	1Ω, 0.1%, 10W, WW	TEPRO	TS10-1Ω	R231-1	1
R219	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	1
R220	100Ω, 0.5W, Var	BECK	72PMR-100Ω	RP97-100	1
R221	681Ω, 1%, 0.5W, MtF	IRC	CEC-TO-681Ω	R94-681	2
R222	681Ω, 1%, 0.5W, MtF	IRC	CEC-TO-681Ω	R94-681	..
R223	1.5kΩ, 10%, 0.25W, Comp	A-B	CB-152-10%	R76-1.5K	4
R224	47Ω, 10%, 0.25W, Comp	A-B	CB-470-10%	R76-47	2
R225	0.39Ω, 5%, 2W, WW	IRC	BWH-2W-.39Ω	R201-0.39	2
R226	0.39Ω, 5%, 2W, WW	IRC	BWH-2W-.39Ω	R201-0.39	..
R227	47Ω, 10%, 0.25W, Comp	A-B	CB-470-10%	R76-47	..
R228	1.5kΩ, 10%, 0.25W, Comp	A-B	CB-152-10%	R76-1.5K	..
R229	820Ω, 10%, 0.25W, Comp.	A-B	CB-821-10%	R76-820	1
R230	150Ω, 10%, 0.25W, Comp.	A-B	CB-151-10%	R76-150	2
R231	150Ω, 10%, 0.25W, Comp.	A-B	CB-151-10%	R76-150	..
R232	1kΩ, 1%, 0.5W, MtF.	IRC	CEC-TO-1kΩ	R94-1K	2
R233	1.5kΩ, 10%, 0.25W, Comp	A-B	CB-152-10%	R76-1.5K	..
R234	1kΩ, 1%, 0.5W, MtF.	IRC	CEC-TO-1kΩ	R94-1K	..
R235	3.3kΩ, 10%, 0.25W, Comp	A-B	CB-332-10%	R76-3.3K	..
R236	333kΩ, 1%, 0.5W, MtF.	IRC	CEC-TO-333kΩ	R94-333K	3
R237	3.32kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-3.32kΩ	R88-3.32K	..
R238	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	4
R239	3.32kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-3.32kΩ	R88-3.32K	..
R240	333kΩ, 1%, 0.5W, MtF.	IRC	CEC-TO-333kΩ	R94-333K	..
R241	3.3kΩ, 10%, 0.25W, Comp	A-B	CB-332-10%	R76-3.3K	..
R242	333kΩ, 1%, 0.5W, MtF.	IRC	CEC-TO-333kΩ	R94-333K	..
R243	100Ω, 10%, 0.25W, Comp.	A-B	CB-101-10%	R76-100	2
R244	100Ω, 10%, 0.25W, Comp.	A-B	CB-101-10%	R76-100	..
R301	5.49kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-5.49kΩ	R88-5.49K	1
R302	100kΩ, 10%, 2W, Comp.	A-B	HB-104-10%	R3-100K	1
R303	1.5kΩ, 10%, 0.25W, Comp	A-B	CB-152-10%	R76-1.5K	..
R304	20Ω, 5%, 2W, WW	IRC	BWH-2W-20Ω	R201-20	1
R305	32.4kΩ, 1%, 0.12W, MtF.	IRC	CEA-TO-32.4kΩ	R88-32.4K	1
R306	10kΩ, 0.5W, Var	BECK	72PMR-10kΩ	RP97-10K	1
R307	464kΩ, 1%, 0.5W, MtF.	IRC	CEC-TO-464kΩ	R94-464K	2
R308	100kΩ, 10%, 1W, Comp.	A-B	GB-104-10%	R2-100K	1
R309	47kΩ, 10%, 2W, Comp	A-B	HB-104-10%	R3-47K	.1
R310	464kΩ, 1%, 0.5W, MtF.	IRC	CEC-TO-464kΩ	R94-464K	..
R311	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	..
R312	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	..
R313	16.63kΩ, 0.1%, 0.12W, MtF	DALE	MFF-1/8-16.63kΩ	R176-16.63K	2
R314	16.63kΩ, 0.1%, 0.12W, MtF	DALE	MFF-1/8-16.63kΩ	R176-16.63K	..
R315	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	..
R316	68Ω, 10%, 0.25W, Comp	A-B	CB-680-10%	R76-68	2
R317	68Ω, 10%, 0.25W, Comp	A-B	CB-680-10%	R76-68	..

SWITCHES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
S101	Range, Rotary Type.	KI	...	SW-360	1
S102	Current, X100, Rotary Type.	KI	...	SW-363	2
S103	Current, X10, Rotary Type	KI	...	SW-363	..
S104	Output Selector, Rotary Type.	KI	...	SW-361	1
S105	Switch, Slide, DPDT	S-C	46206LR	SW-365	1
S106	Switch, Slide, DPDT	S-C	XW2776	SW-394	2
S107	Switch, Slide, DPDT	S-C	XW2776	SW-394	..
S108	LO (Ground-Float), SPST	C-W	GF-323SPST	SW-392	..
S301	Switch, Toggle, SPDT.	ALCO	MST-105D	SW-236	1
S302	Switch, DPDT.	C-W	GG350PC-DPDT	SW-318	2
S303	Switch, DPDT.	C-W	GG350PC-DPDT	SW-318	..

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
U101	Transistor Array, 14-pin DIP.	RCA	CA3086	IC-53	1
U102	Operational Amplifier, 8-pin DIP.	FAIR	Special	IC-77	1
U103	Operational Amplifier, 8-pin, TO-99 Case.	NAT	LM308H	IC-67	2
U104	Operational Amplifier, 8-pin, TO-99 Case.	NAT	LM308H	IC-67	..
U201	Operational Amplifier, 8-pin DIP.	NAT	LM307N	IC-61	2
U202	Operational Amplifier, 8-pin DIP.	NAT	LM307N	IC-61	..
U203	Operational Amplifier, 8-pin, TO-99 Case.	RCA	CA3080	IC-91	2
U204	Operational Amplifier, 8-pin, TO-99 Case.	RCA	CA3080	IC-91	..
U205	Operational Amplifier, 8-pin DIP.	FAIR	Special	IC-76	1
U206	Operational Amplifier, 8-pin DIP.	NAT	LM301AN	IC-24	1
U301	12V Regulator, Case TO-220.	FAIR	UGH7812393	IC-60	2
U302	12V Regulator, Case TO-220 (*Selected IC-60).	FAIR	UGH7812393	*26839A	..
U303	Operational Amplifier, 8-pin DIP.	FAIR	U9T7741393	IC-42	2
U304	Operational Amplifier, 8-pin DIP.	FAIR	U9T7741393	IC-42	..

MISCELLANEOUS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
B301	Fan, 105CFM, 115V, 60 Hz, 19W	HOW	3-90-8010	FN-2	1
M101	Meter, 250μA, linerar movement	AMMON	FM-1	ME-96	1
T301	Transformer	KI	Special	TR-148	1
TK301	Thermal Breaker, SPST, Open: 185°F, Closed: 135°F	THERM	36T21	TB-1	1
W501	Jumper	KI	--	J-3	1
--	Dial, for selector switch S102.	KI	--	25781A	-
--	Dial, for selector switch S103.	KI	--	25781A	-
--	Dial, for output control R124	KI	--	25783A	-
--	Dial, for Range Switch S101	KI	--	25785A	-
--	Knob, for Output Selector Switch S104	KI	--	25151A	-
--	Knob, for Voltage Compliance Control R101	KI	--	25151A	-

Parts Located on PC-396 (See Schematic 27266C)

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C501	10 F, 20V, ETT	COMPI	TD2-20-106-20	C-179-10M	..
C502	0.47 F, 20V, ETT	COMPI	TD1-20-474-20	C-179-0.47M	1
C503	4.7 F, 20V, ETT	COMPI	TD1-20-475-20	C-179-4.7M	..

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
CR501	Rectifier, 75mA, 75V	TEXAS	1N914	RF-28	..
CR502	Rectifier, 75mA, 75V	TEXAS	1N914	RF-28	..
CR503	Rectifier, 75mA, 75V	TEXAS	1N914	RF-28	..
CR504	Rectifier, 75mA, 75V	TEXAS	1N914	RF-28	..
CR505	Rectifier, 75mA, 75V	TEXAS	1N914	RF-28	..

CONNECTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
P501	5-pins.	KI	.....	24249A	..
P502	5-pins.	KI	.....	24249A	..

TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q501	N-Chan jFET, Case R110.	INTSL	ITE4392	TG-77	4
Q502	N-Chan jFET, Case R110.	INTSL	SELECTED	27283A*	..
Q503	N-Chan jFET, Case R110.	INTSL	ITE4392	TG-77	..
Q504	N-Chan jFET, Case R110.	INTSL	ITE4392	TG-77	..

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R501	1MΩ, 10%, 0.25W, Comp	A-B	CB-105-10%	R-76-1M	..
R502	100kΩ, 10%, 0.25W, Comp	A-B	CB-104-10%	R-76-100K	..
R503	1MΩ, 10%, 0.25W, Comp	A-B	CB-105-10%	R-76-1M	..
R504	820kΩ, 10%, 0.25W, Comp	A-B	CB-821-10%	R-76-820K	1
R505	100kΩ, 10%, 0.25W, Comp	A-B	CB-104-10%	R-76-100K	..
R506	100kΩ, 10%, 0.25W, Comp	A-B	CB-104-10%	R-76-100K	..
R507	1MΩ, 10%, 0.25W, Comp	A-B	CB-105-10%	R-76-1M	..
R508	1MΩ, 10%, 0.25W, Comp	A-B	CB-105-10%	R-76-1M	..
R509	1kΩ, 10%, 0.25W, Comp	A-B	CB-102-10%	R-76-1K	..

CABLES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J501	Connector, Housing, 5-pins	BERG	65039-040	CS-251	2
J502	Connector, Housing, 5-pins	BERG	65039-040	CS-251	..

NOTE

Cables J501 and J502 connect between PC-396 and PC-331 as shown on schematic 27266C. Connections P208 through P216 are located on PC-331 (See schematic 27266C and 26626E).

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C401	100pF, 1000V, CerD.	CENLB	DD-101	C64-100P	1
C402	33pF, 1000V, CerD	CENLB	DD-330	C64-33P	1
C403	0.1μF, 250V, MtF.	AMPRX	C280AE/P100K	C178-0.1	1
C404	1.2μF, 20V, ETT	COMPI	TD1-20-125-20	C179-1.2M	2
C405	1.2μF, 20V, ETT	COMPI	TD1-20-125-20	C179-1.2M	..
C406	0.33μF, 50V, CerF	ERIE	8131050651-334M	C237-0.33M	1
C407	0.01μF, 500V, CerD.	ERIE	871-Z5U0-103M	C22-0.01M	1

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
CR401	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	10
CR402	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR403	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR404	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR405	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR406	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR407	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR408	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR409	Zener, 6.2V, 1/4W (Selected).	MICRO	MC6778	DZ-57	1
CR410	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR411	Zener, 5.8V	DICK	1N706	DZ-1	1
CR412	Rectifier, 1A, 800V	MOT	4006	RF-38	1
CR413	Rectifier, 75mA, 75V.	TEXAS	1N914	RF-28	..
CR414	Zener, 15V.	DICK	1N718	DZ-18	1

DISPLAYS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DS401	LED, 2V, 40mA (red)	LITRO	RL209	26746A*	2
DS402	LED, 2V, 40mA (red)	LITRO	RL209	26746A*	..

*Selected from Keithley PL-61

CONNECTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J401	15-pin, Remote Program (Female)	CAN	DAM-15S	CS-303	1
J402	10-pin.	BERG	20052	CS-237	3
J403	5-pin	BERG	20370	CS-251	1
J404	10-pin.	BERG	20052	CS-237	..
J405	10-pin.	BERG	20052	CS-237	..
J406	2-pin	BERG	65039-035	CS-266	2
J407	2-pin	BERG	65039-035	CS-266	..

P402 P403 P404 P405 P406	Part of circuit board, pc-342				

RELAYS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
K401	DPDT, 6V.	BAB	K2T-6V-1	RL-42	7
K402	DPDT, 6V.	BAB	K2T-6V-1	RL-42	..
K403	DPDT, 6V.	BAB	K2T-6V-1	RL-42	..
K404	DPDT, 6V.	BAB	K2T-6V-1	RL-42	..
K405	DPDT, 6V.	BAB	K2T-6V-1	RL-42	..
K406	DPDT, 6V.	BAB	K2T-6V-1	RL-42	..
K407	DPDT, 6V.	BAB	K2T-6V-1	RL-42	..
K408	DPDT, 24V	BAB	K2T-24V-1	RL-43	1

TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q401	NPN, Case TO-92	MOT	2N3904	TG-47	3
Q402	JFET.	MOT	2N4391	TG-80	1
Q403	NPN, Case TO-92	MOT	2N3904	TG-47	..
Q404	NPN, Case TO-92	MOT	2N3904	TG-47	..
Q405	PNP, Power Type, Case TO-5.	RCA	2N5416	TG-105	1
Q406	NPN, Case TO-106.	FAIR	2N3565	TG-39	2
Q407	NPN, Case TO-106.	FAIR	2N3565	TG-39	..

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R401	22kΩ, 10%, 0.25W, Comp.	A-B	CB-223-10%	R76-22K	3
R402	56kΩ, 10%, 0.25W, Comp.	A-B	CB-563-10%	R76-56K	1
R403	499kΩ, 0.5%, 0.5W, MtF.	DALE	MFF-1/2-T9	R171-499K	1
R404	1.8kΩ, 10%, 0.25W, Comp	A-B	CB-182-10%	R76-1.8K	1
R405	10kΩ, Cermet.	BECK	89P-10K	RP89-10K	2
R406	1.1kΩ, 1%, 0.125W, MtF.	IRC	CEA-TO-1.1kΩ	R88-1.1K	1
R407	2kΩ, Cermet	BECK	89P-2K	RP89-2K	1
R408	499kΩ, 0.12%, 1W, MtF	DALE	MFF-1/8-T9-499K	R177-499K	2
R409	499kΩ, 0.12%, 1W, MtF	DALE	MFF-1/8-T9-499K	R177-499K	..
R410	475kΩ, 0.12%, 1W, MtF	DALE	MFF-1/8-T9-475K	R177-475K	1
R411	49.9kΩ, 0.12%, 1W, MtF.	DALE	MFF-1/8-T9-49.9K	R177-49.9K	1
R412	10kΩ, Cermet.	BECK	89P-10K	RP89-10K	..
R413	1kΩ, 0.12%, 1W, MtF	DALE	MFF-1/8-T9-	R177-1K	1
R414	6.8kΩ, 10%, 0.25W, Comp	A-B	CB-223-10%	R76-6.8K	..
R415	10kΩ, 1%, 0.125W, MtF	IRC	CEA-TO-10kΩ	R88-10K	2
R416	2.2MΩ, 10%, 0.25W, Comp	A-B	CB-225-10%	R76-2.2M	1
R417	10kΩ, 1%, 0.125W, MtF	IRC	CEA-TO-10kΩ	R88-10K	..
R418	6.04kΩ, 0.1%, 0.125W, MtF	DALE	MFF-1/8-6.04K	R179-6.04K	1
R419	28kΩ, 0.1%, 0.125W, MtF	DALE	MFF-1/8-28K	R179-28K	1
R420	3.3kΩ, 10%, 0.25W, Comp	A-B	CB-332-10%	R76-3.3K	1
R421	100kΩ, 10%, 0.25W, Comp	A-B	CB-104-10%	R76-100K	2
R422	4.7kΩ, 10%, 0.25W, Comp	A-B	CB-472-10%	R76-4.7K	2
R423	1MΩ, 10%, 0.25W, Comp	A-B	CB-105-10%	R76-1M	1
R424	2.2kΩ, 10%, 0.25W, Comp	A-B	CB-225-10%	R76-2.2K	..
R425	4.7kΩ, 10%, 0.25W, Comp	A-B	CB-472-10%	R76-4.7K	..
R426	10kΩ, 1%, 0.125W, MtF	DALE	MFF-1/8-10K	R168-10K	2
R427	4.75kΩ, 1%, 0.125W, MtF	IRC	CEA-TO-4.75K	R88-4.75K	1
R428	10kΩ, 10%, 0.25W, Comp.	A-B	CB-103-10%	R76-10K	..
R429	22kΩ, 10%, 0.25W, Comp.	A-B	CB-223-10%	R76-22K	..
R430	9.09kΩ, 1%, 0.125W, MtF	IRC	CEA-TO-9.09K	R88-9.09K	1
R431	1kΩ, 1%, 0.125W, MtF.	IRC	CEA-TO-1K	R88-1K	1
R432	10kΩ, 1%, 0.125W, MtF	DALE	MFF-1/8-10K	R168-10K	..
R433	29.4kΩ, 0.12%, 1W, MtF.	DALE	MFF-1/8-T9-29.4K	R177-29.4K	1
R434	100kΩ, 10%, 1.0W, Comp.	A-B	GB-104-10%	R2-100K	1
R435	100kΩ, 10%, 0.25W, Comp	A-B	CB-104-10%	R76-100K	..
R436	3.09kΩ, 0.12%, 1W, MtF.	DALE	MFF-1/8-T9-3.09K	R177-3.09K	2
R437	3.09kΩ, 0.12%, 1W, MtF.	DALE	MFF-1/8-T9-3.09K	R177-3.09K	..
R438	50kΩ, Cermet.	BECK	89P-50K	RP89-50K	1
R439	715Ω, 1%, 0.125W, MtF	IRC	CEA-TO-715	R88-715	1

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
U401	Operational Amplifier, 8-pin DIP (*Selected).	NAT	LM308N*	26426A	1
U402	Operational Amplifier, 8-pin, Case TO-99.	NAT	LM308H	IC-67	1
U403	Operational Amplifier, 8-pin DIP.	FAIR	Special	IC-77	1
U404	Operational Amplifier, 8-pin DIP.	FAIR	UGT7741393	IC-42	2
U405	Isolator, 6-pin DIP	FAIR	FCD820	IC-82	1
U406	Operational Amplifier, 8-pin DIP.	FAIR	UGT7741393	IC-42	..

COMPONENTS LOCATED ON PC-330

Circuit Desig.	Location Code	Circuit Desig.	Location Code	Circuit Desig.	Location Code
C101	G-4	Q102	G-3	R132	A-3
C102	F-4			R133	C-4
C103	F-2	R102	H-4	R134	E-4
C104	G-3	R103	F-4	R135	A-1
C105	F-5	R104	G-4	R136	E-1
C106	F-1	R105	F-4	R137	F-2
C107	B-3	R106	F-4	R138	F-2
C108	B-3	R107	G-3	R139	F-2
C109	A-3	R108	G-3	R140	C-3
C110	A-2	R109	G-3	R141	D-3
C111	F-3	R110	G-3	R142	D-3
		R111	F-2	R143	D-3
CR101	F-4	R112	F-4	R144	D-3
CR102	F-3	R113	F-4	R145	D-3
CR103	F-4	R114	B-2	R146	D-4
CR104	G-3	R115	C-2	R147	D-4
CR105	B-3	R116	C-2	R148	A-2
CR106	C-3	R117	D-3	R149	D-3
CR107	E-2	R118	C-4		
CR108	E-2	R119	C-2		
CR109	D-2	R120	B-3	S101	G-2
CR110	A-1	R121	B-3	S102	B-2
		R122	C-3	S103	C-1
DS101	E-1	R123	C-3	S104	E-3
DS102	F-1	R125	D-2	S105	A-2
DS103	C-1	R126	D-2	S106	C-3
DS104	G-4	R127	D-2	S107	D-4
		R128	A-2		
F101	E-1	R129	A-4	U102	C-3
		R130	D-2	U103	B-3
Q101	F-3	R131	A-3	U104	E-2

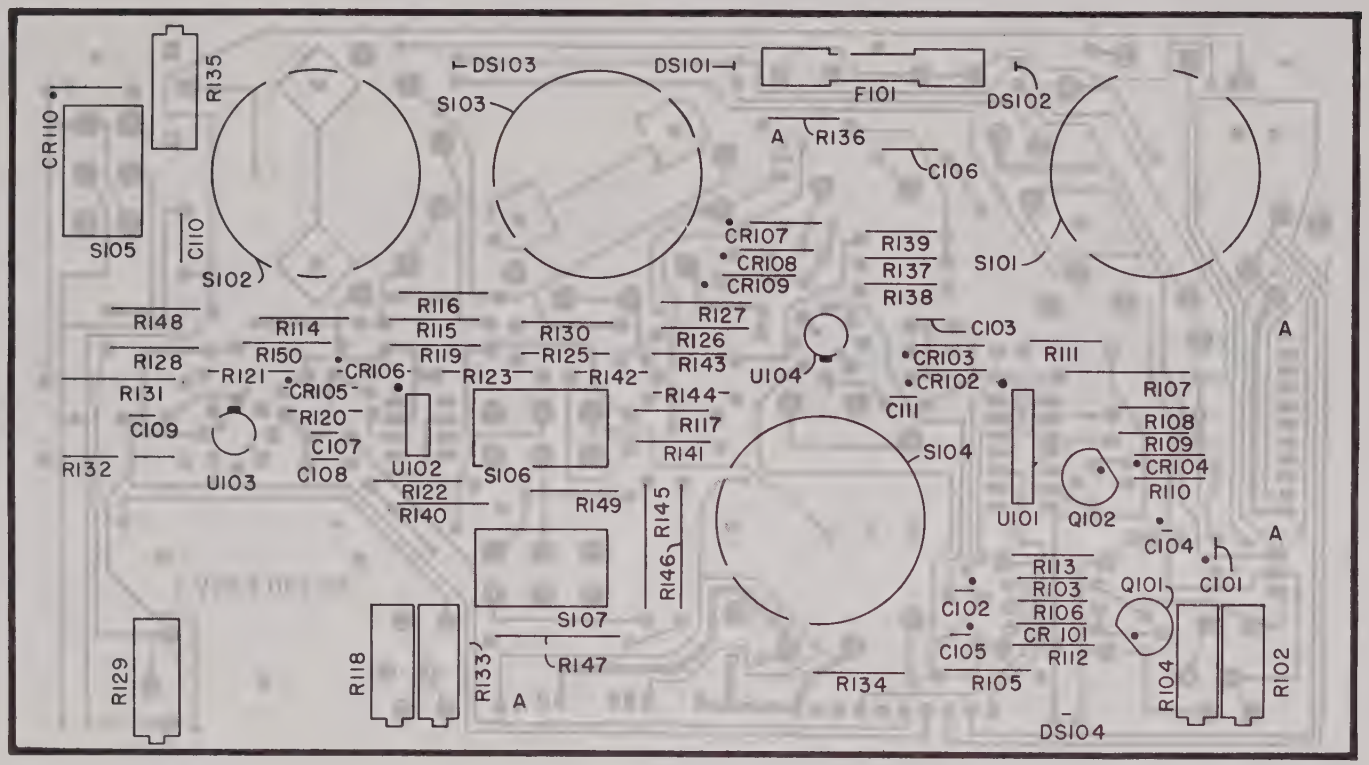


FIGURE 33. Component Layout, PC-330.

COMPONENTS LOCATED ON PC-331

Circuit Desig.	Location Code	Circuit Desig.	Location Code	Circuit Desig.	Location Code	Circuit Desig.	Location Code
C201	A-2	CR207	C-6	Q307	H-5	R239	A-7
C202	A-2	CR208	C-7			R240	B-5
C203	A-2	CR209	A-6	R201	A-2	R241	A-7
C204	A-3	CR210	A-7	R202	A-1	R242	B-6
C205	A-4	CR211	C-3	R203	B-4	R243	B-5
C206	B-4	CR212	D-2	R204	A-3	R244	B-5
C207	A-4			R205	A-2		
C208	B-2	CR301	L-4	R206	A-2	R301	K-5
C210	C-2	CR302	K-4	R207	B-3	R302	L-4
C211	B-2	CR303	L-7	R208	B-3	R303	L-5
C212	C-4	CR304	G-4	R209	A-3	R304	K-6
C213	C-5	CR305	K-5	R210	A-3	R305	L-7
C214	C-6	CR306	K-5	R211	C-4	R306	K-7
C215	C-6	CR307	K-5	R212	B-4	R307	L-6
C216	A-6			R213	B-2	R308	L-5
C217	A-5	P201	A-4	R214	B-4	R309	K-6
C218	B-5	P202	A-4	R215	A-4	R310	L-5
C219	B-7	P203	B-1	R216	B-4	R311	J-7
C220	B-5	P205	C-1	R217	B-5	R312	J-7
C221	A-6	P206	B-2	R218	C-5	R313	H-6
C222	D-7			R219	C-4	R314	H-6
		Q201	D-4	R220	C-2	R315	H-6
C301	K-2	Q202	G-5	R221	C-2	R316	H-6
C302	L-2	Q203	D-3	R222	D-2	R317	H-6
C303	K-4	Q204	D-3	R223	D-3		
C304	L-6	Q205	D-3	R224	D-3	S302	M-1
C305	K-6	Q206	C-3	R225	E-3	S303	M-2
C306	H-7	Q207	G-7	R226	E-3		
C307	H-7	Q208	C-4	R227	C-3	TK301	H-6
C308	J-6	Q209	C-6	R228	D-3		
C309	H-5	Q210	D-7	R229	C-3	U201	A-2
C310	H-5	Q211	D-7	R230	D-5	U202	B-4
C311	K-5	Q212	E-5	R231	D-5	U203	B-4
C312	L-6			R232	C-5	U204	B-4
		Q301	K-5	R233	D-7	U205	B-2
CR201	B-3	Q302	J-5	R234	C-6	U206	B-6
CR202	A-3	Q303	L-5	R235	A-6		
CR203	C-3	Q304	K-6	R236	A-6	U301	K-7
CR204		Q305	K-6	R237	A-7	U302	H-6
CR205	D-6	Q306	H-5	R238	A-6	U303	J-7
CR206	C-6					U304	H-7

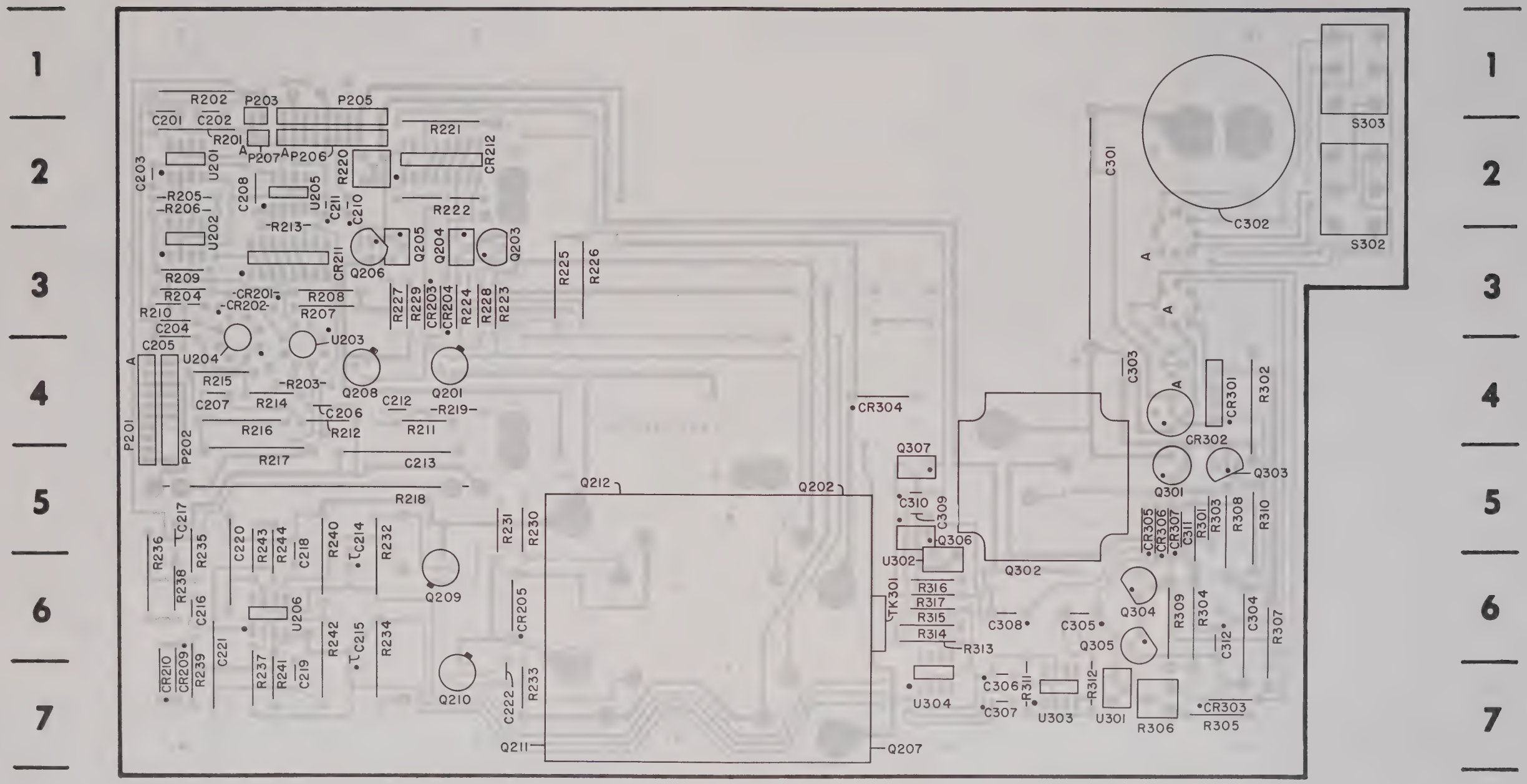


FIGURE 34. Component Layout, PC-331.

COMPONENTS LOCATED ON PC-342

Circuit Desig.	Location Code	Circuit Desig.	Location Code	Circuit Desig.	Location Code	Circuit Desig.	Location Code
C401	C-3	J402	D-1	R401	D-3	R423	F-1
C402	G-3	J403	G-2	R402	B-3	R424	F-1
C403	G-3	J404	C-2	R403	A-3	R425	F-1
C404	E-2	J405	E-2	R404	B-3	R426	E-3
C405	E-2	J406	G-1	R405	G-1	R427	E-3
C406	G-3			R406	A-3	R428	D-3
C407	F-2	K401	B-1	R407	A-1	R429	D-3
		K402	B-3	R408	A-3	R430	D-3
CR401	B-2	K403	B-3	R409	A-3	R431	D-3
CR402	B-2	K404	C-2	R410	A-2	R432	F-3
CR403	C-2	K405	D-2	R411	G-2	R433	A-3
CR404	C-2	K406	E-2	R412	G-1	R434	G-3
CR405	D-1	K407	F-2	R413	D-3	R435	F-3
CR406	E-1	K408	G-2	R414	F-3	R436	A-2
CR407	F-1			R415	G-2	R437	A-2
CR408	G-2	Q401	F-3	R416	G-2	R438	A-2
CR409	A-2	Q402	D-2	R417	G-3	R439	G-2
CR410	C-3	Q403	D-3	R418	G-2		
CR411	C-3	Q404	F-1	R419	F-3	U401	F-3
CR412	B-3	Q405	B-3	R420	F-3	U402	B-3
CR413	C-3	Q406	G-3	R421	G-1	U403	E-3
CR414	G-3	Q407	C-3	R422	F-1	U404	G-3
						U405	G-1
DS401	G-3					U406	D-3
DS402	G-3						

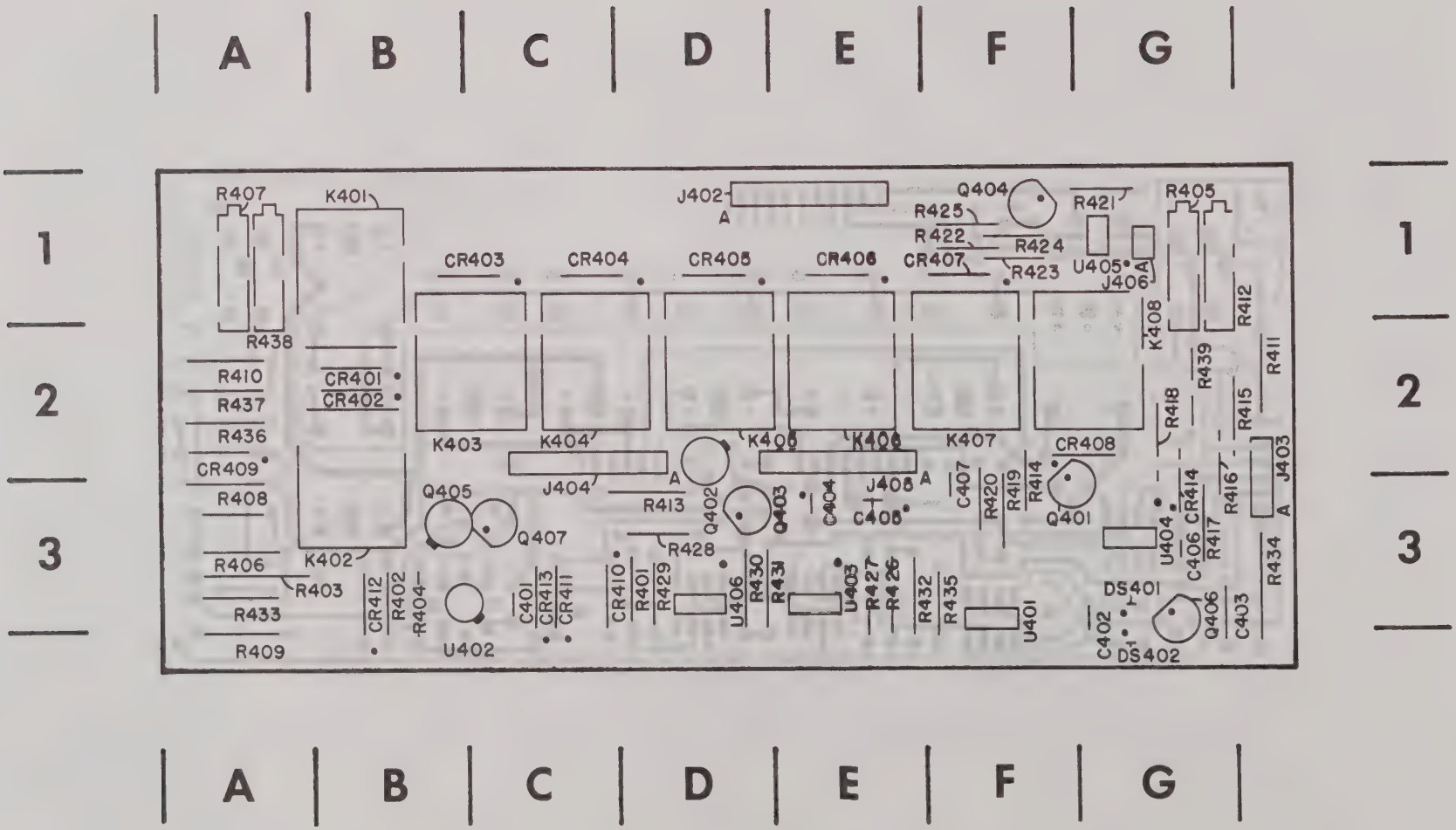


FIGURE 35. Component Layout, PC-342.

COMPONENTS LOCATED ON PC-396

Circuit Desig.	Location Code	Circuit Desig.	Location Code
C501	B-3	Q502	C-1
C502	B-2	Q503	B-3
C503	A-2	Q504	B-1
CR501	B-2	R501	B-3
CR502	B-1	R502	B-2
CR503	B-2	R503	B-1
CR504	A-3	R504	B-2
CR505	A-3	R505	A-1
P501	C-2	R506	A-2
P502	A-2	R507	A-1
Q501	C-3	R508	A-2
		R509	A-2

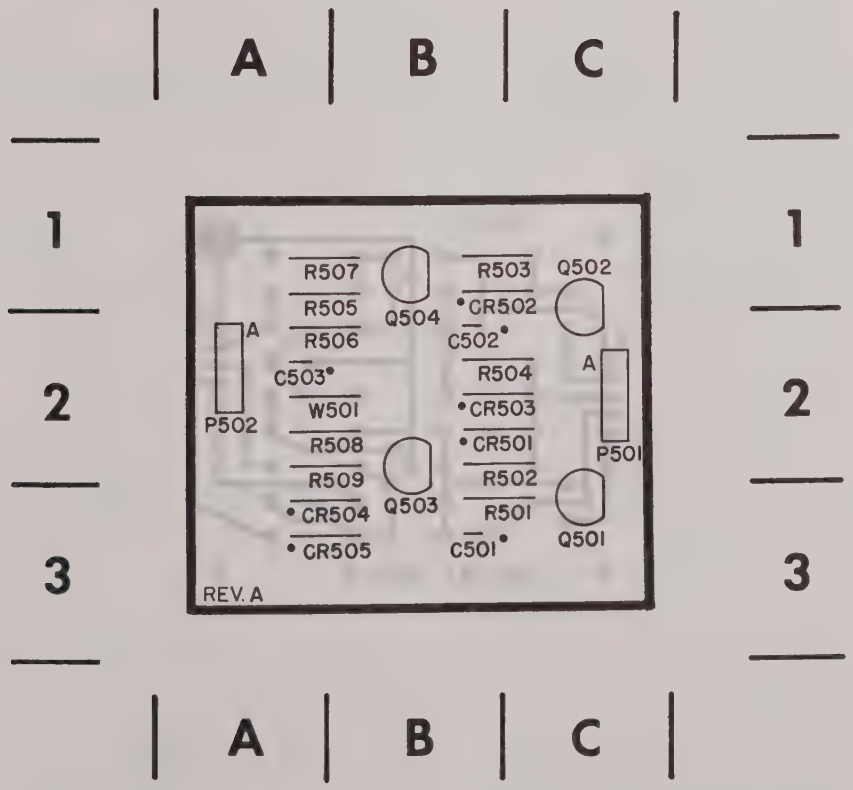


FIGURE 36. Component Layout, PC-396.

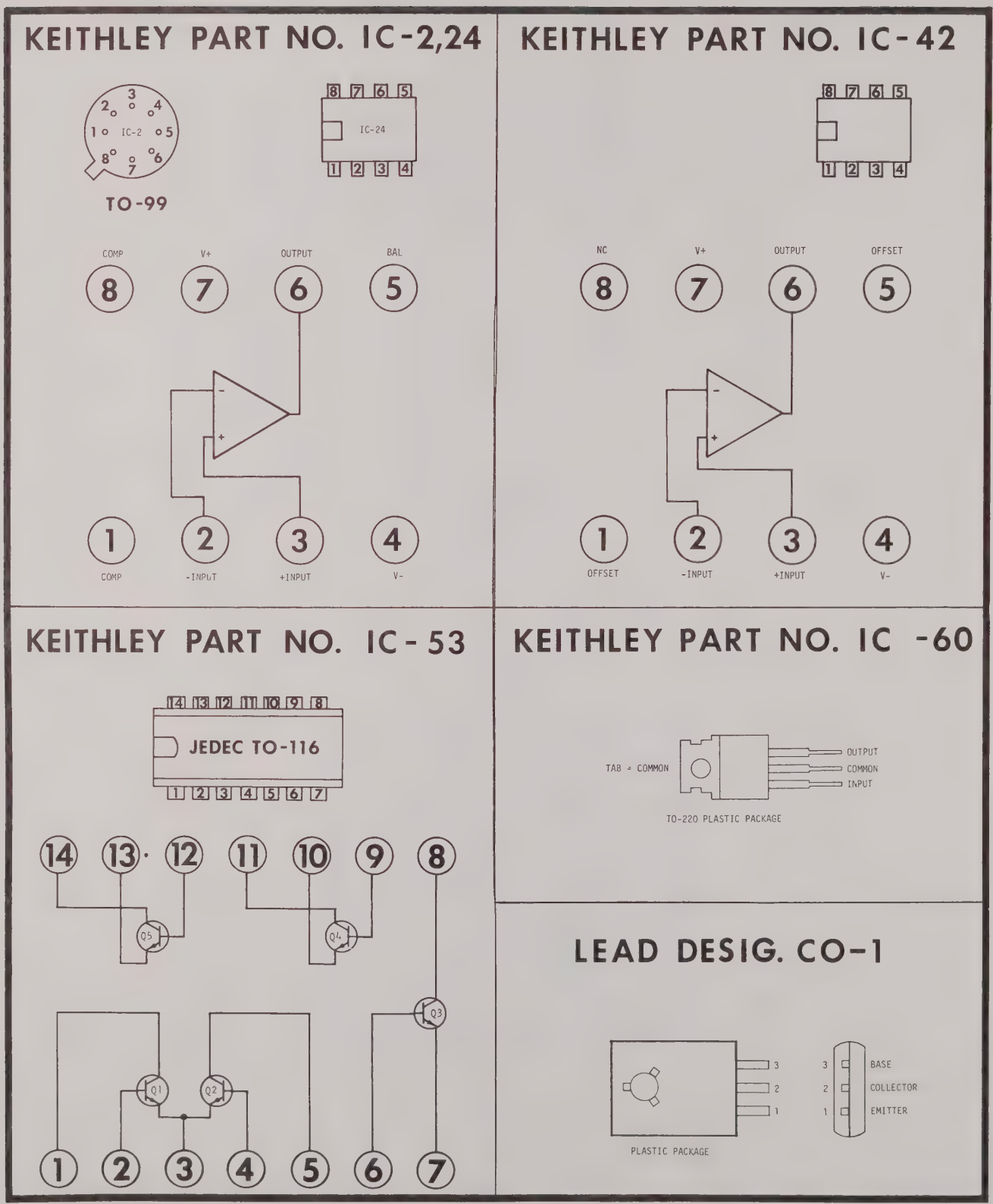


FIGURE 37. Case Outlines, Integrated Circuits.

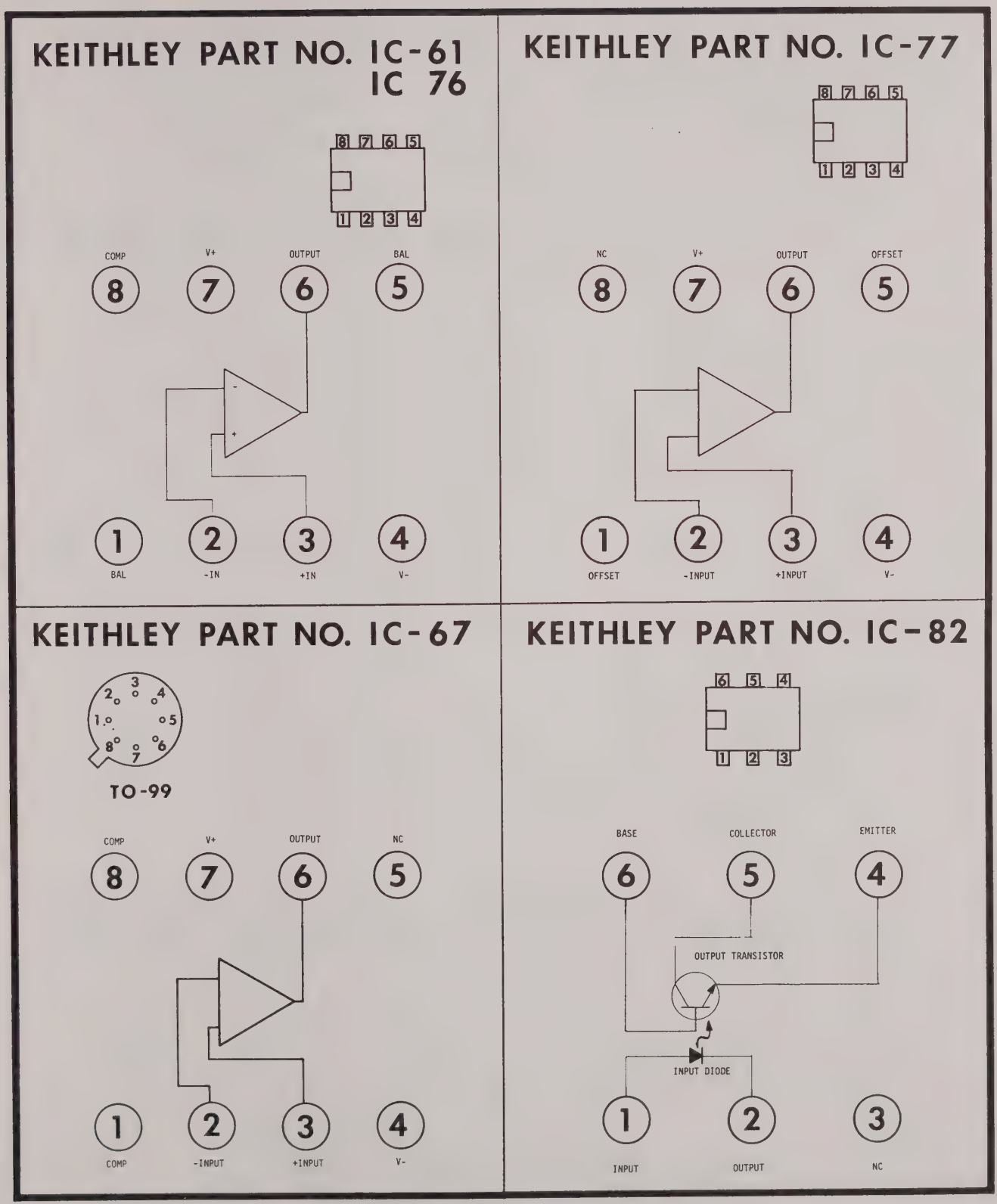
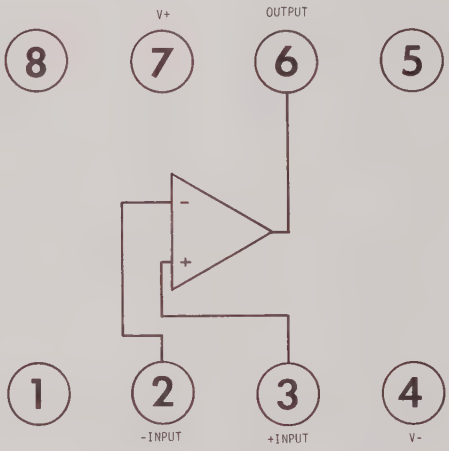


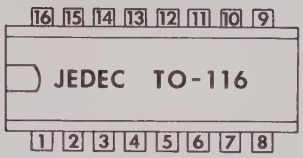
FIGURE 38. Case Outlines, Integrated Circuits.

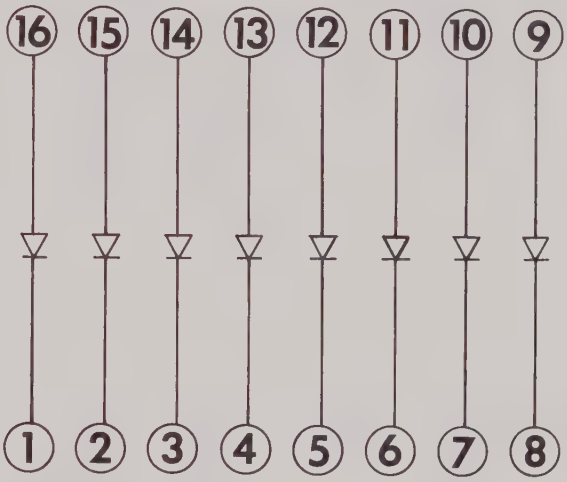
KEITHLEY PART NO. IC-91

TO-99

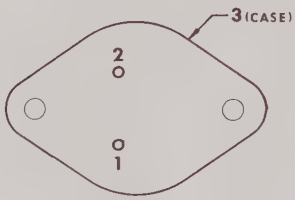


KEITHLEY PART NO. DN-2



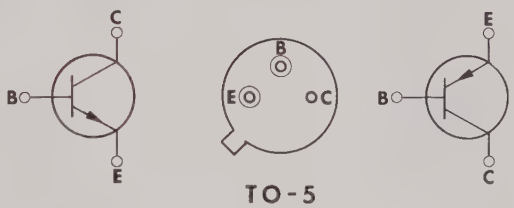


LEAD DESIG. TO-3



TO-3

LEAD DESIG. TO-5



TO-5

LEAD DESIG. TO-92

TO-92

BOTTOM VIEW

LEAD DESIG. TO-106

TO-106

BOTTOM VIEW

FIGURE 39. Case Outlines, Transistors.

DO NOT SCALE THIS DRAWING	KEITHLEY INSTRUMENTS CLEVELAND OHIO	GENERAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 3-18-76	SCALE	SCHEMATIC, CURRENT SOURCE
		.XX ± .03 .XXX ± .010	MATERIAL	DWN J.C. CHK	NO 26226E
		ANGULAR ± 1°		APPR	
		FINISH		SURFACE MAX	

USED ON		
MODEL	NEXT ASSEMBLY	QTY
237		

C R206	C R207	J207	
C R208	R204	C209	R140

REFERENCE DESIGNATIONS NOT USED

U206	J206	P216			
R244	C222	CR212		Q210	
Q102	U104	M101	J111	F101	
R142	C112	CR112	S108	D8104	

HIGHEST REFERENCE DESIGNATIONS

SCHEMATIC 262270 POWER SUPPLY

NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS, M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. ○ DENOTES FRONT PANEL CONTROL.
4. ● DENOTES REAR PANEL CONTROL.
5. ⊘ DENOTES INTERNAL ADJ.
6. ◄ DENOTES CLOCKWISE ROTATION.
7. ⏚ DENOTES EARTH GROUND.
8. ⏚ DENOTES SIGNAL GROUND "LO".
9. ▷ FLAGNOTES WITH SAME NUMBERS ARE CONNECTED.
10. ROTARY SWITCHES SHOWN IN C.C.W. POSITION.
11. * DENOTES NOMINAL VALUE SELECTED AT FACTORY.
12. J206B TO BE USED WHEN REMOTE PROGRAMMING BOARD IS INSTALLED. SEE SCHEMATIC 26421D.

PC 330 SWITCH BD.

PC 331 MOTHER BD.

LTR	ECO NO	REVISION	DATE
A	0-9421	PC.L.A.S.S.C.	1-13-74
B	4446	CH'G FUSE FROM ⅝ TO ¾ A	9-13-74
C	4574	TRANSIENT SUPPRESSION CKT	12-17-74
D	4603	ADD J201 & J202	1-23-75
E	4837	CHANGE R138, R139 VALUES	6-2-75
F	5005	ADD VALUES FOR 115VAC & 230VAC OPERATION	9-23-75

LTR	ECO NO	REVISION	DATE
G	5684	ADDED TRIM POT R142	12-22-75
H	5861	ADDED R143 & CR213 TO PROTECT DVM INPUT.	5-1-76
J	7382	R139 WAS 6.8K	11-25-80

26226E

SCORE

DO NOT SCALE THIS DRAWING	KEITHLEY INSTRUMENTS CLEVELAND, OHIO		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	TOLERANCES .XX ± .01 .XXX ± .005 ANGLES ± 1/2°	TITLE SCHEMATIC PROGRAMMING OPTION	
MATERIAL	FINISH	SCALE	DATE
	BLAST ACE MAX		
			NO 266086

MODEL	PART ASSEMBLY	QTY
237		

USED ON

SCHEMATIC DESIGNATIONS NOT USED

HI-HEST SCHEMATIC DESIGNATION USED

R439	CR407	CR407	CR414
LM106	K406	DS402	J406
P406			

NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K=KILOHMS, M=MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF=MICROFARADS)
3. ⊘ INDICATES INTERNAL ADJ.
4. ← INDICATES CLOCKWISE ROTATION.
5. ALL RELAY CONTACTS ARE SHOWN IN THE NON-ENERGIZED POSITION.
6. JUMPER CLIPPED DURING FINAL CALIBRATION IF NECESSARY.

C	2381	J202 thru J206B, added P/N	
B			
A	4-4-1980		
LTR	ECO NO	REVISION	DATE

(See DWG. 262266)

P405 J405 J206B (SEE DWG. 262266)

P4 J404 J202 (See DWG. 262266)

P406 J406

J402 P402

J403 P403

J401 J402 P402

COMPLIANCE LIMIT

INTERNAL ± 12 V. SUPPLY

COMPLIANCE REFERENCE

COMPLIANCE AMPLIFIER

+ H.V.

+325 V.

DISABLE REMOTE PROGRAMMING

REMOTE PROGRAMMING

CURRENT SOURCE HIGH

100 mA

10 mA

1000 µA

COMPLIANCE LIMIT FLAG (+5 V. TRUE)

GUARD 3,11

RESISTANCE PROGRAMMING (CURRENT)

EXTERNAL OPERATE

COMPLIANCE SPAN SELECT

1000 mA

100 mA

10 mA

1000 µA

+ 5V. EXTERNAL SUPPLY

+5V

-12V

+12V

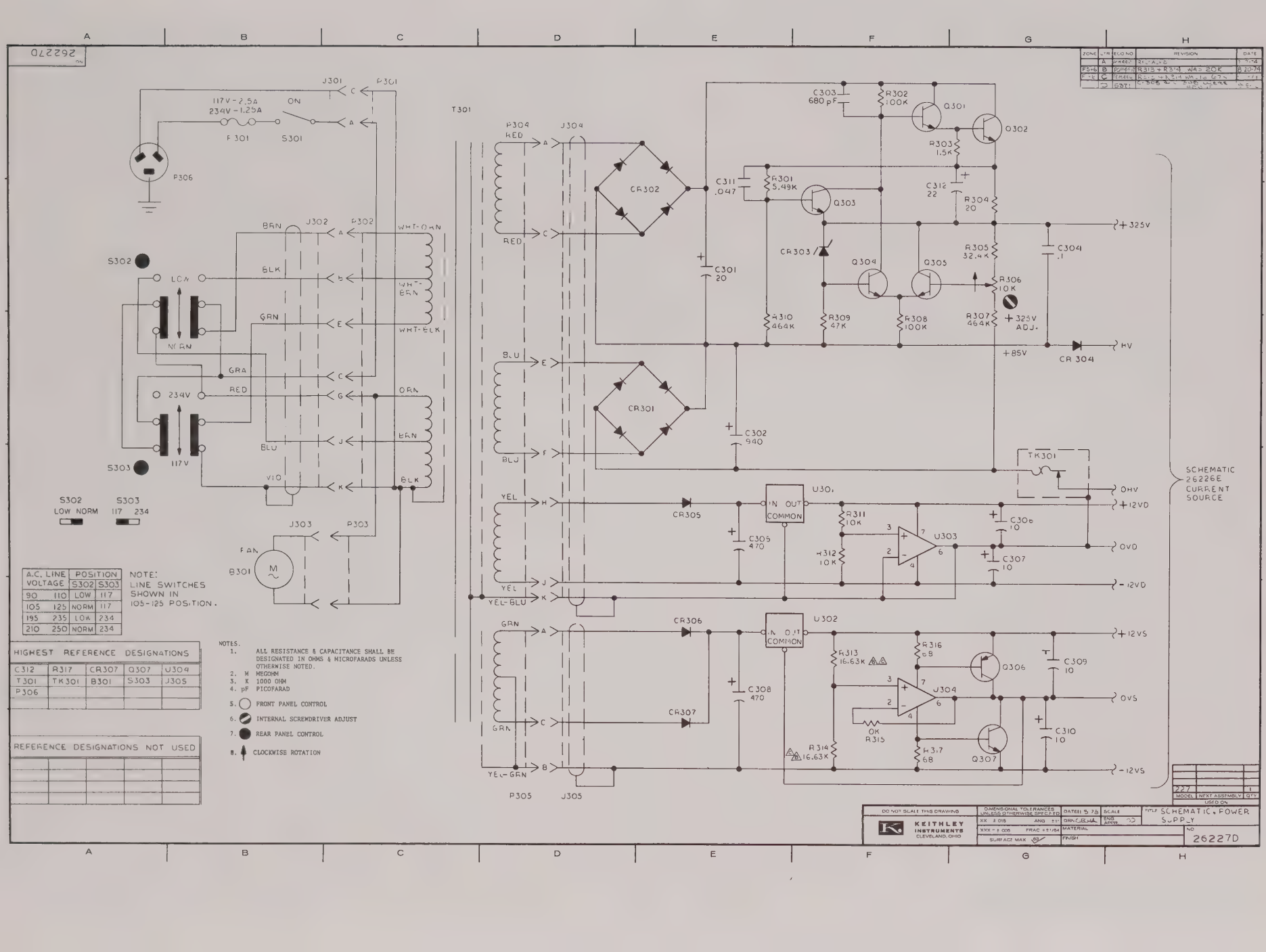
0V

CURRENT CAL.

ZERO ADJ.

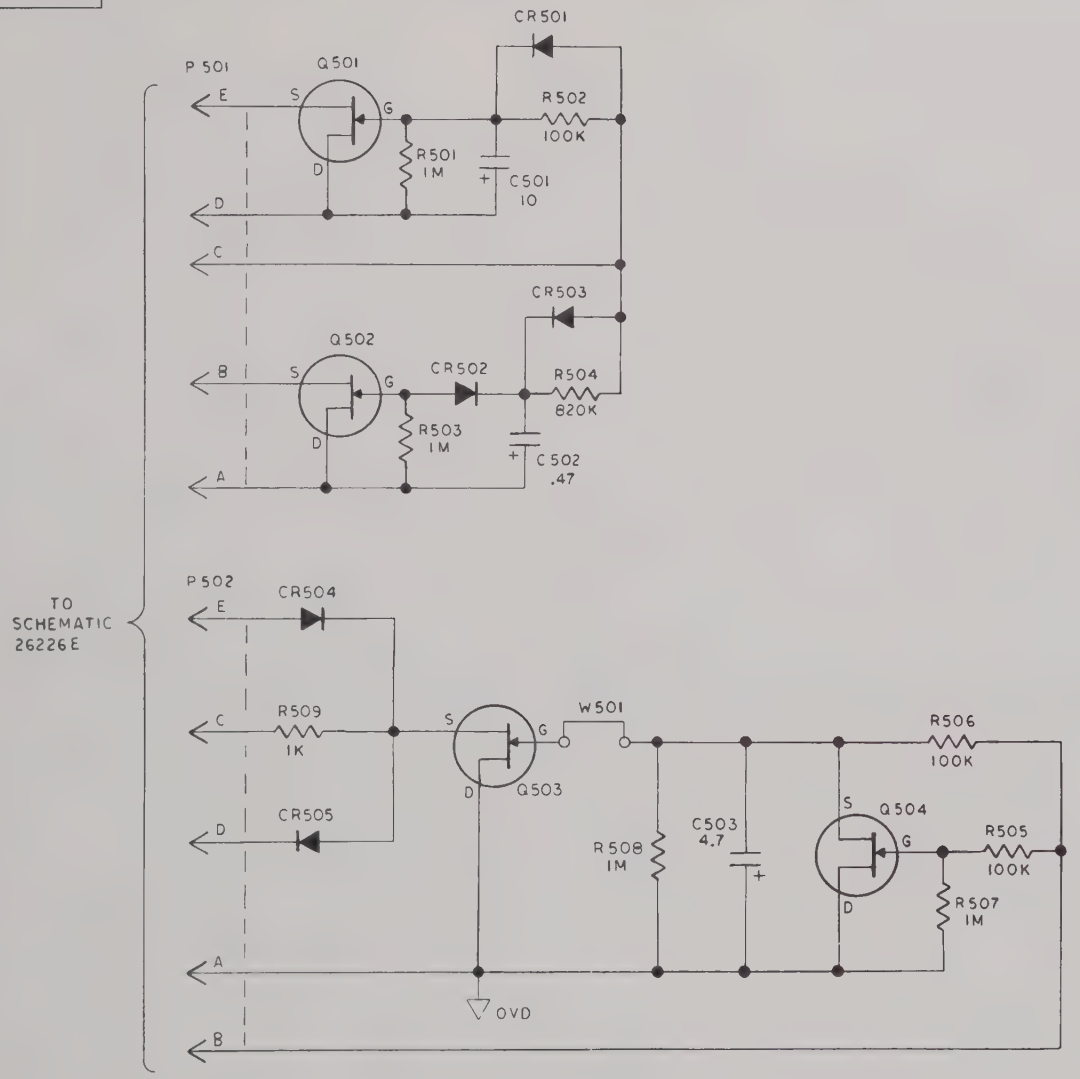
CURRENT SOURCE ADJ.

MAX. COMP. ADJ.


26227D
117V - 2.5A
234V - 1.25A
ON
F 301
S301
P306
J301
P301
T301
S302
S303
LOW NORM
117V
234V
BRN
BLK
GRN
GRA
RED
VIO
ORN
WHT-ORN
WHT-BRN
WHT-BLK
J302
P302
FAN
B301
J303
P303
S302 S303
LOW NORM 117 234
A.C. LINE VOLTAGE
POSITION S302 S303
90 110 LOW 117
105 125 NORM 117
195 235 LOW 234
210 250 NORM 234
NOTE: LINE SWITCHES SHOWN IN 105-125 POSITION.
HIGHEST REFERENCE DESIGNATIONS
C312 R317 CR307 Q307 U304
T301 TK301 B301 S303 J305
P306
REFERENCE DESIGNATIONS NOT USED
NOTES.
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. M MEGOHM
3. K 1000 OHM
4. pF PICOFARAD
5. FRONT PANEL CONTROL
6. INTERNAL SCREWDRIVER ADJUST
7. REAR PANEL CONTROL
8. CLOCKWISE ROTATION
P304 J304
RED
BLU
YEL
YEL-BLU
GRN
YEL-GRN
P305 J305
CR302
CR301
CR305
CR306
CR307
CR303
CR 304
C303 680 pF
C311 .047
C301 20
C302 940
C305 470
C308 470
C312 22
C304 .1
C306 10
C307 10
C309 10
C310 10
R302 100K
R303 1.5K
R301 5.49K
R304 20
R305 32.4K
R306 10K
R307 464K
R308 100K
R309 47K
R310 464K
R311 10K
R312 10K
R313 16.63K
R314 16.63K
R315 0K
R316 68
R317 68
Q301
Q302
Q303
Q304
Q305
Q306
Q307
+325V
+325V ADJ.
+85V
HV
U301
U302
U303
U304
IN OUT COMMON
TK301
OHV
+12VD
OVD
-12VD
+12VS
OVS
-12VS
SCHEMATIC 26226E CURRENT SOURCE
ZONE LTR ECO NO REVISION DATE
A
B
C
D
DO NOT SCALE THIS DRAWING
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX ± .015 ANG ±1°
XXX ± .005 FRAC ± 1/64
SURFACE MAX 63
KEITHLEY INSTRUMENTS CLEVELAND, OHIO
DATE 5-23
DRAWN
ENG APPR.
MATERIAL
FINISH
SCALE
TITLE SCHEMATIC, POWER SUPPLY
NO 26227D
MODEL 227
NEXT ASSEMBLY
QTY 1
USED ON

27226C

LTR	ECO NO	REVISION	DATE
A	4603	RELEASED	1-22-75



NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS, M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. ⏚ DENOTES SIGNAL GROUND "LO".

HIGHEST SCHEMATIC DESIGNATIONS USED		
C503	W501	
CR503		
Q504		
R509		

SCHEMATIC DESIGNATIONS NOT USED		

227		
MODEL	NEXT ASSEMBLY	QTY
	USED ON	

DO NOT SCALE THIS DRAWING

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX - ± 015 ANG ± ±1
XXX - ± 005 FRAC ± ±1/64
SURFACE MAX 63

DATE 1-22-75 SCALE ~
DRN RJK ENG APPR RCD
MATERIAL —
FINISH —

KEITHLEY INSTRUMENTS
CLEVELAND OHIO

TITLE SCHEMATIC PC-396

NO 27266C

KEITHLEY

SERVICE FORM

Model No. _____ **Serial No.** _____ **P.O. No.** _____ **Date** _____

Name _____ **Phone** _____

Company _____

Address _____

City _____ **State** _____ **Zip** _____

List all control settings and describe problem. _____

_____

_____

_____ (Attach additional sheets as necessary.)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.) _____

What power line voltage is used? _____ Variation? _____

Frequency? _____ Ambient Temperature? _____ °F.

Variation? _____ °F. Rel. Humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe below.)

_____

_____

*Be sure to include your name and phone number on this service form.

KEITHLEY

Keithley Instruments, Inc./28775 Aurora Road/Cleveland, Ohio 44139/U.S.A./(216) 248-0400/Telex: 98-5469
WEST GERMANY: Keithley Instruments GmbH/Heiglhofstrasse 5/D-8000 München 70/314 289/Telex: 1345000
GREAT BRITAIN: Keithley Instruments, Ltd./1, Boulton Road/Reading, Berkshire RG2 ONL/(0734) 86 12 87/Telex: 847047
FRANCE: Keithley Instruments SARL/2 Bis, Rue Léon Blum/B.P. 60/91121 Palaiseau Cedex/(6) 0115 155/Telex: 600933
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